

Soils as an Exposure Pathway for Lead in Vermont:

Problems and Solutions on the Statewide and Residential Scales

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Executive Summary

The Soils Spectrums Project Group, composed of five Middlebury College Environmental Studies seniors in a capstone course, formed to study how soil acts as an exposure pathway for lead, thereby harming human health. Although lead poisoning is relatively well understood and its use in gasoline and paint has been banned for decades, it remains a chronic problem across the United States. The relative importance of soils as an exposure pathway has increased over the past few years. The Vermont Department of Health's Healthy Homes Lead Poisoning Prevention Program (HHLPPP) identified soil lead as a problem that better understanding and more specific public outreach materials could improve.

Our analysis of soil lead operates at two different scales: statewide and residential. For the statewide analysis, we aggregated and mapped soil lead data from four Vermont organizations. The map reveals areas where lead levels are high and where there has been less testing. We conclude that sites with high lead levels occur across the state. Within Burlington, soil lead levels have an uneven distribution that may be a result of differences in housing stock age. This database of soil lead tests can be kept up-to-date if all testing organizations continue to add their data. We also created a "riskscape"¹ map of lead that uses the distance of Vermont homes from roadways to predict where historic tailpipe emissions from leaded gasoline likely contaminated yards. We recommend that this riskscape be used by the HHLPPP and other lead-focused health organizations to prioritize proactive soil testing sites.

At the residential scale we measured the drip zone, or the area near buildings where paint falls to the ground after peeling and weathering from walls, windows, and doors. The drip zone analysis measured the spatial extent of unsafe soil lead levels as you move away from exterior walls painted with lead paint. We measured soil lead at six homes that had at one point been painted with leaded paint in Middlebury, VT, sampling along a transect up to 10 feet from the exterior wall of the house. With 95% confidence, our model predicts that soil lead levels drop below the EPA standard of 400 ppm 7 feet from the house. We recommend that homeowners, gardeners, and daycare centers locate gardens and play areas at least 7 feet from buildings built before 1978. There is major variation among houses depending on region, paint history, other sources of contamination, and soil disturbance around the house, so this is only a guideline.

The HHLPPP identified a need for more soil-related lead outreach and educational materials.² Our outreach materials incorporate results from the drip zone analysis with existing best practices recommended by the HHLPPP, independent organizations, the EPA, and Departments of Health from other states. We created a web-based informational document and a paper tri-fold pamphlet that we hope will reach a broad and diverse section of Vermonters and inspire them to manage their yards and gardens to reduce lead exposure.

Finally, we present a policy brief that draws on policy approaches used in other states to recommend improvements to Vermont's current lead laws. Vermont's laws on childhood lead poisoning are effective and we do not recommend they be changed, instead we suggest changes to policy that will help secure funding and improve compliance with current lead

¹ Morello-Frosch R, Pastor M, Sadd J. Environmental justice and southern California's "riskscape": the distribution of air toxics exposures and health risks among diverse communities. *Urban Affairs Rev.* 2001;36:551–578.

² Haugen, Andrea. 2014. Healthy Homes Lead Poisoning Prevention Program Manager, Vermont Department of Health. Personal Communication.

laws. These include (1) a fee on paint sales to subsidize further childhood lead poisoning prevention efforts and (2) mandatory health insurance coverage of blood lead tests and follow-up medical care. New lead legislation is in the early stages of development by the Department of Health and interested legislators, and we hope that this brief can contribute to their process.

List of Acronyms

ANR: Agency of Natural Resources
BLL: Blood Lead Level ($\mu\text{g}/\text{dL}$ “micrograms per deciliter”)
BLP: Burlington Lead Program
CDC: Center for Disease Control
VDH: Vermont Department of Health
EMP: Essential Management Practices
EPA: U.S. Environmental Protection Agency
ES401: Middlebury College Environmental Studies Senior Seminar 401
GFAAS: Graphite Furnace Atomic Absorption Spectrometry
GIS: Geographic Information Systems
GIV: Governor’s Institute of Vermont (at the University of Vermont)
HHLPPP: Healthy Homes Lead Poisoning Prevention Program
IQ: Intelligence Quotient
KML: Keyhole Markup Language
N: sample size in a statistical analysis
NCHH: National Center for Healthy Housing
Pb: Lead (elemental symbol)
ppb: parts per billion
ppm: parts per million
R: a specific statistical software
THO: Town Health Officer
TSCA: Toxic Substances Control Act (1976)
US: United States
UVM: University of Vermont
VHCB: Vermont Housing Conservation Board
VT: Vermont
XRF: X-Ray Fluorescence

1. Introduction

The Soils Spectrums Project Group formed to study how soil acts as an exposure pathway for lead, thereby harming human health. The group is comprised of undergraduate students in Middlebury College's Senior Seminar in Environmental Studies, a community-connected, project-based class that focused on lead contamination the fall semester of 2014. The two other project groups in the seminar (1) studied lead contamination of compost and possible implications of lead-contaminated yard debris for Vermont's Universal Recycling Law and (2) created outreach materials about lead specifically designed for the refugee populations settled in Vermont.

Although regulations such as the Toxic Substances Control Act that banned lead in paint in 1978 and the 1986 ban of lead in gasoline have dramatically reduced the introduction of new lead to the environment, lead remains a persistent contaminant in the built and natural environment. In Vermont, lead primarily enters soils from paint chips that weather off the sides of homes. Once in the soil, lead adsorbs to clay and silt particles and resides in situ permanently, unless physically eroded away with the clay or leached out under very acidic conditions.³ This means lead does not pose a major threat to groundwater, but it does remain at or near the surface of the soil indefinitely, creating a permanent poisoning problem for Vermont that can only be addressed with remediation and education.

Working in partnership with the Vermont Department of Health Healthy Homes Lead Poisoning Prevention Program (HHLPPP), we sought to analyze and add to the soil lead data available for Vermont, create outreach materials that HHLPPP can distribute to the public, and outline policy options that may be suitable for mitigating lead exposure in Vermont.

Although lead poisoning is relatively well understood and its use in gasoline and paint has been banned for decades, it remains a chronic problem across the United States. Children exposed to lead through indoor paint or dust, soil, toys, or other pathways, can have lifelong health effects. In a 2014 letter to health care providers, Vermont Department of Health (VDH) Commissioner Harry Chen wrote, "An overwhelming body of research shows long-term and irreversible cognitive and behavioral effects with even mildly elevated blood lead levels in young children."⁴ With 69% of Vermont homes built before the 1978 lead paint ban, paint is the leading cause of lead exposure in the state.

As of 2013, 8.2% and 7.2% of Vermont's 1- and 2-year-olds, respectively, tested at blood lead levels (BLL) higher than the reference value of 5µg/dL.⁵ Lead exposure at these young ages is linked to reduced IQ and cognitive disorders. Country-wide *declines* in soil lead levels in the 1970s and '80s were even responsible for the drop in violent crime rates 20 years later.^{6,7,8} While these effects are obviously important for our state's health and quality of life, they also directly affect our economy. As children affected by lead grow older they cost the state in terms of

³ Elless, M. P., Bray, C. A. & Blaylock, M. J. 2007. Chemical behavior of residential lead in urban yards in the United States. *Environmental Pollution* 148: 291–300.

⁴ Quoted by Andrea Haugan, Program Chief of the HHLPPP, in her 9 Sept. 2014 presentation to Middlebury College Environmental Studies Senior Seminar.

⁵ Andrea Haugan, 9 Sept. 2014 presentation to Middlebury College Environmental Studies Senior Seminar

⁶ Carlson, C., Feng, Y.-S., McClurg, D., and Trummel, J. 2006. The costs of lead poisoning in Vermont. Dartmouth Center for Evaluative Clinical Sciences, Dartmouth, NH

⁷ Drum, K. 2013. America's real criminal element: Lead. *Mother Jones* 1. Accessed 24 Oct 2014. <<http://www.motherjones.com/environment/2013/01/lead-crime-link-gasoline>>

⁸ Reyes, J.W. 2007. Environmental policy as social policy? The impact of childhood lead exposure on crime. *The B.E. Journal of Economic Analysis and Policy* 7(1): article 51. <<http://www.bepress.com/bejeap/vol7/iss1/art51>>

educational expenses, medical expenses, and loss of earnings.⁹ A 2006 study by the Dartmouth Center for Evaluative Clinical Sciences conservatively estimated the costs to the state of Vermont for children with BLL >10µg/dL at \$15 million annually.¹⁰ Including children with BLL 5-10µg/dL in this calculation raises the estimated annual cost to \$80 billion. These estimates are conservative given that they do not include the less easily-quantified costs of juvenile delinquency and violent behavior.¹¹

This report has four major sections. It begins with our two analyses of soil lead levels in Vermont at both statewide and local scales, continues into the outreach materials designed to convey those analyses and other information to the public, and concludes with a policy brief.

For the statewide analysis of soil lead, we mapped existing soil lead data across VT. The map reveals areas where lead levels are high and where there has been less testing. We conclude that high soil lead levels occur across the state. Within Burlington, soil lead levels have an uneven distribution that may be a result of differences in the age of housing stock. This database of soil lead tests can be kept up-to-date if all testing organizations continue to add their data. We also created a “riskscape”¹² map that uses the distance of VT homes from roadways to predict where historic tailpipe emissions from leaded gasoline likely contaminated yards. We recommend that this riskscape be used by the HHLPPP and other lead-focused health organizations to prioritize proactive soil testing sites.

At the backyard scale we measured the drip zone, or the area near buildings where paint falls to the ground after weathering from walls, windows, and doors. With 95% confidence, our model predicts that soil lead levels drop below the EPA standard of 400 ppm 7 feet from the house. We recommend locating gardens and play areas at least 7 feet away from buildings built before 1978. Because factors besides distance cause variation in the data, this is only a guideline; soils farther than 7 feet should not be assumed to be lead-free.

The HHLPPP identified a need for more soil-related lead outreach and educational materials.¹³ Our outreach materials incorporate results from the drip zone analysis with existing best practices recommended by the HHLPPP, independent organizations, the EPA, and Departments of Health from other states. We created a web-based informational document and a paper tri-fold pamphlet that we hope will reach a broad and diverse section of Vermonters and inspire them to manage their yards and gardens to reduce lead exposure.

Finally, we present a policy brief that draws on policy approaches used in other states to recommend improvements to Vermont’s current lead laws, specifically regarding funding and compliance. We recommend (1) a fee on paint sales to subsidize further childhood lead poisoning prevention efforts and (2) mandatory health insurance coverage of blood lead tests and follow-up medical visits. We hope that this brief can contribute to new lead legislation being developed by the VDH.

This report serves as the explanatory vehicle for a number of accompanying deliverables: maps, drip zone results, brochures, and a policy brief. We hope that those materials will be living documents of practical use and that they will be updated as the HHLPPP and its partner organizations gather new information.

⁹ Carlson et al. 2006

¹⁰ Ibid.

¹¹ Ibid.

¹² Morello-Frosch R, Pastor M, Sadd J. Environmental justice and southern California’s “riskscape”: the distribution of air toxics exposures and health risks among diverse communities. *Urban Affairs Rev.* 2001;36:551–578.

¹³ Haugen, Andrea. 2014. Healthy Homes Lead Poisoning Prevention Program Manager, Vermont Department of Health. Personal Communication.

2. Geographic Analysis

2.1. Introduction

A statewide geographic analysis of soil lead levels will allow the Department of Health and other agencies to identify where soil lead is most problematic and where more testing is needed. Our goal was to aggregate and map all publicly available soil lead data for VT and layer that data over population density and soil lead risk factors. We created these maps with the intention that confidential blood lead level (BLL) data could later be internally added by the HHLPPP to better elucidate the relationship between risk factors and poisoning cases. Additionally, we hope that our aggregated data and maps can be a shared, living database that all VT lead organizations can contribute to and use. The VDH has expressed interest in housing this database, and Diane Munroe, Coordinator for Community-Based Environmental Studies at Middlebury College, will facilitate the transfer of data and establishment of the structure.

We draw on a robust history of soil lead research to better inform our geographic analysis of Vermont. In 2014, a meta-analysis of soil lead studies across the U.S. confirmed that soil lead levels are highest in urban centers, are positively correlated with population density, and only change very gradually over time.¹⁴ The study extracted and aggregated data from 84 studies, and independently analyzed the aggregated data to answer questions independent of the original studies. Across the U.S., historic emissions from burning leaded gasoline remain the primary explanation for soil lead levels, especially in and around urban centers.¹⁵ In aggregating results from many different studies of cities and regions across the country, they needed to represent each city with a single value. They chose to represent each study of each city by minimum, maximum, median, and mean soil lead levels, and they preserved metadata such as location type (residential, parks, gardens, commercial, industrial, near lead point source, etc.).¹⁶ Preserving these metadata allowed them to see that outlier cities had point sources of lead or were sampled in known lead-contaminated areas.¹⁷ In almost all studies observed soil lead levels were significantly higher in the center of the city and decreased outwards. Rural locations consistently had lower soil lead levels than urban locations.¹⁸

A study mapping soil lead levels and associated blood lead levels in New Orleans found that soils were 3 to 38 times safer in outlying areas than in the urban center.¹⁹ This study differentiated locations by whether they were on busy streets, residential streets, house sides, or open spaces. In the inner city, median soil lead was 367 ppm on busy streets, 313 ppm on residential streets, 1228 ppm at house sides, and 103 ppm in open areas (Figure 1). In the outlying regions, soil lead was 64, 46, 32, and 28 ppm, respectively. They attribute this significant difference to higher traffic flows, older housing stock, and crowded housing in the center city.²⁰

¹⁴ Datko-Williams, L., Wilkie, A., and Richmond-Bryant, J. 2014. Analysis of U.S. soil lead (Pb) studies from 1970 to 2012. *Science of the Total Environment* 468-469: 854-863.

¹⁵ Ibid., p. 854

¹⁶ Ibid., p. 856

¹⁷ Ibid., p. 857

¹⁸ Ibid., p. 861

¹⁹ Mielke, H.W., Gonzales, C.R., Powell, E.T., and Mielke, P.W. 2013. Environmental and health disparities in residential communities of New Orleans: The need for soil lead intervention to advance primary prevention. *Environment International* 51: 73-81.

²⁰ Ibid., p. 80

The authors also suggest that the safe soil lead standard should be 40 ppm rather than 400 because the EPA uses a factor of 10 as its margin of safety for ingested toxins. Although less experienced in the fields of toxicology and lead poisoning policy, we disagree for two reasons. First, the factor of 10 is used for regularly ingested toxins,²¹ and soil is not a food product nor is it purposefully ingested for any reason. Second, only 5-10% of the total lead in urban soils is bioavailable.²²

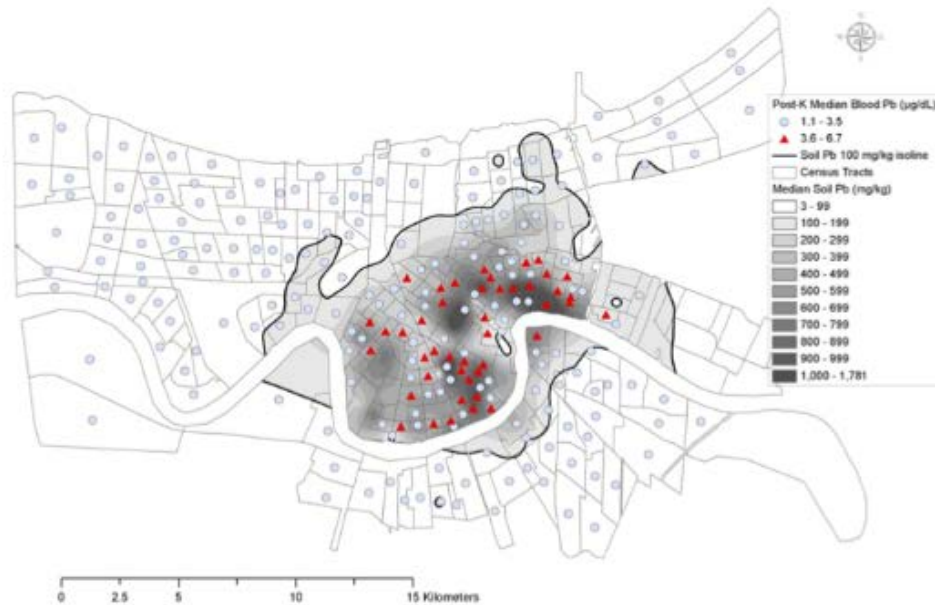


Figure 1. Post-Katrina spatial distribution of interpolated median census tract soil lead (ppm), in shades of gray. Median Blood Lead Levels are shown in red triangles and blue circles. Copied from Mielke et al. 2013.

Another recent study of soil lead focused on small-urban residential neighborhoods, and used high spatial resolution mapping to determine whether the primary source of contamination was paint or gasoline.²³ The area of study was the oldest neighborhoods in Appleton, Wisconsin, a small city of 72,623 people, or a little less than twice the population of Burlington, Vermont.²⁴ Authors sampled yard soils at 170 properties and used the inverse distance weighting scheme in ArcGIS 10.1 Spatial Analyst to map soil lead levels across the study area.²⁵ They found large ranges in soil lead levels both across the study area (47 to 32,483 ppm), and within individual properties. Within properties, drip-zone samples were significantly higher than mid-yard samples, and the consistency of this result indicated that the primary source of soil lead contamination in the area was historic lead paint rather than leaded gasoline.²⁶ They attribute

²¹ Ibid., p. 79

²² Zia, M.H., Codling, E.E., Scheckel, K.G., and Cheney, R.L. 2011. *In vitro* and *in vivo* approaches for the measurement of oral bioavailability of lead (Pb) in contaminated soils: A review. *Environmental Pollution* 159: 2320-2327.

²³ Clark, J.J., and Knudsen, A.D. 2014. Extent, characterization, and sources of soil lead contamination in small-urban residential neighborhoods. *Journal of Environmental Quality* 42: 1498-1506.

²⁴ U.S. Census Bureau. 2010. Appleton (city), Wisconsin. *State and County QuickFacts*. Accessed 6 Nov 2014, via quickfacts.census.gov.

²⁵ Clark and Knudsen, 2014.

²⁶ Ibid., p. 1501

within-yard data not conforming to this pattern to historic structures that have been removed and to soil disturbance or redistribution. They conclude that although leaded gasoline is the primary source of contamination for large cities like New Orleans, Baltimore, and Chicago, lead-based exterior paint may be the main source in smaller urban communities.²⁷

These three geographic studies of soil lead informed our approach to the state-wide analysis in a number of ways. First, in accordance with the first meta-analysis, we chose to represent each property sampled with the highest lead level found on that site. This approach also allowed us to have a valid data point for each site; because the data came from different organizations, the sampling methodology and metadata collection varied dramatically among the data. Compilation of any variable other than maximum level would prevent us from using data for many sites, for example only 218 of the 354 total testing sites had data specific to drip zones. Second, the studies indicate that preserving metadata can reveal important trends and causal factors, such as age of housing stock. Although the variation in metadata made this compilation incomplete, its importance in the literature motivated us to preserve and clean what metadata we found. Finally, the disparity in soil lead contamination between urban and rural environments made it clear that we would need to make a separate map of Burlington, in addition to the statewide map.

In creating maps of environmental data, it is important to ensure that the map communicates the intended information. There are many ways to represent data spatially, and many options can be misleading or disengaging. In 2012, two population health scientists studied the effects of different data representation styles on “risk belief,” or the message the viewer understands about risk.²⁸ The study compared viewer responses to a choropleth map, dot map, and table representing the same data on well water test results. Viewers were asked to explain what they understood from each map and what it made them feel about well water safety in the area. The choropleth map colored townships with a shade of red indicating the proportion of well sites tested with a certain level of contamination. The dot map represented each tested well with a colored dot representing its level of contamination. These maps communicated substantially different meanings, with the choropleth map suggesting county-wide trends and the dot map indicating local trends and specific information. The largest proportion of study participants preferred the dot map “because it concretely illustrated the amount and location of test results across the county.”²⁹ The authors also concluded that presenting several views of the same information supports better comprehension. In accordance with this finding, we created multiple maps showing different versions of the same data and openly shared the data files so that they can be further used by the HHLPPP and any other organization.

2.2. Methods

Publicly available soil lead testing data was acquired from the Vermont Housing Conservation Board (VHCB n=121), Burlington Lead Program (BLP n=98), and the Governor’s Institute of Vermont on Environmental Science and Technology (GIV n=95) reports. Data from the BLP were in individual lab result files, so data were manually copied from those files into a Microsoft Excel spreadsheet. VHCB data were either in printed forms from inspections or in lab

²⁷ Ibid., p. 1503

²⁸ Severtson, D.J., and Vatovec, C. 2012. The theory-based influence of map features on risk beliefs: Self-reports of what is seen and understood for maps depicting an environmental health hazard. *Journal of Health Communication* 17: 836-856.

²⁹ Ibid., p. 852

result files, and both of these were collected manually from the VHCB office in Montpelier, VT. The GIV data were available as Excel spreadsheets online via the University of Vermont. Middlebury area data collected by the authors for the drip zone analysis were also included, as were residential compost data collected throughout the Champlain Valley by another group of the Middlebury College ES401 Seminar (ES401 n=38).

Sampling at many of the locations yielded multiple soil lead levels because readings were taken at multiple locations around the perimeter, in play areas, mid-yard, and other sites. To create an aggregate dataset that could compare lead levels across sites, we needed to represent each site with only one data point. We assessed three different ways for representing locations: the location's maximum lead level, the average lead level found in the immediate perimeter of the house, and the average lead level found in other places sampled on the property. Because not every property had drip zone data and readings from other places, only the first parameter (maximum lead) has a value for every location. Out of 353 total location points, only 218 had drip zone data and 243 had other property data. The average soil levels found in other areas of the yard, outside the drip zone, were significantly lower than either the property max or the drip zone averages (Figure 2, two t-tests, 2-tailed, heteroscedastic, $p < 0.05$). There was no significant difference between the average property maximum and the average drip zone (Figure 2). Average property maximum was likely brought down by inclusion of properties with low lead levels that did not include a drip-zone analysis, yielding the counter-intuitively and insignificantly lower average for property maximum than for drip zones average. Since non-drip zone areas of the yard tend to have much lower lead levels on average, properties without drip zone data were excluded from the drip zone average, but contributed low "property maxima" to that average. Because property maximum was the only way to get a complete dataset, and because it was comparable with drip zone averages, we chose to represent each property by its maximum. This means that our map shows a worst case scenario, and we recommend using a similar map in conjunction with other data layers that show only results collected by a similar methodology for a more complete understanding of the soil lead landscape.

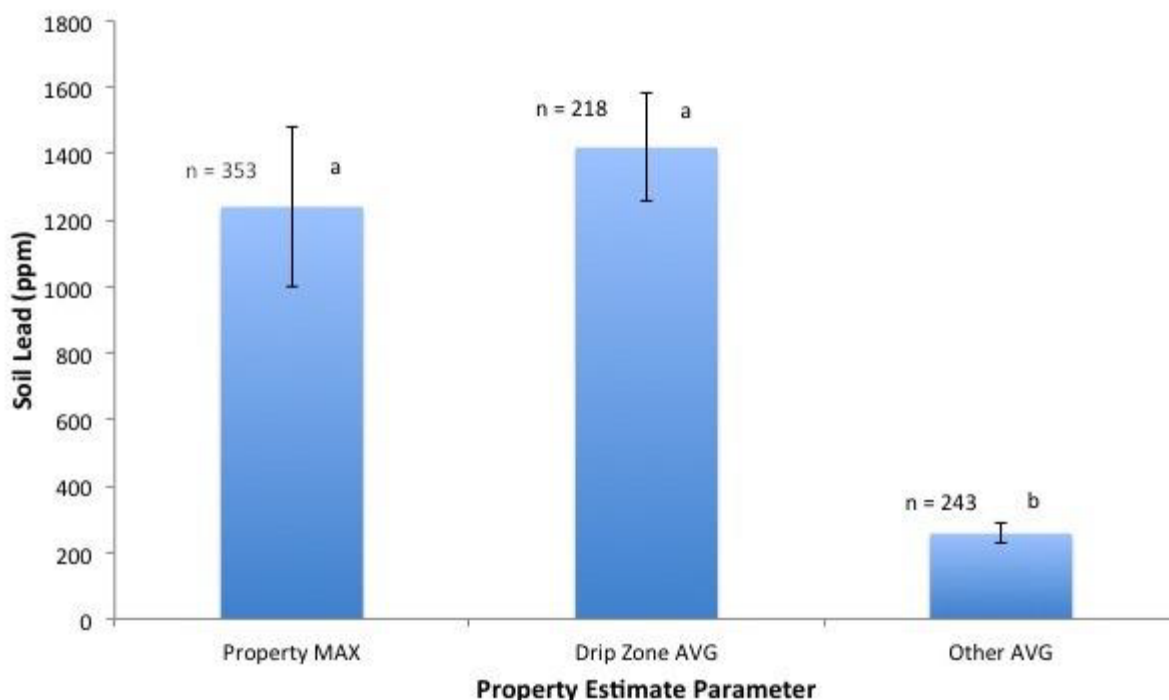


Figure 2. Averages of existing soil lead level data in Vermont by three different property estimate parameters. Data are compiled from the BLP, VHCB, GIV and Middlebury College. “Other AVG” is the average of readings from mid-yards, play areas, gardens, and compost. Error bars show standard error. Bars sharing letters are not statistically different ($p < 0.05$ by heteroscedastic two-tailed t-tests).

In addition to mapping existing soil lead data, we built a predictive model of spatial distributions of lead in soil resulting from decades of leaded gasoline use. As noted above, we compiled and organized other data sets from lead-related organizations around Vermont to better understand where there has been soil testing and where there are cases of lead exposure via soil. Though we realize the majority of exposure cases in Vermont are linked directly to lead paint, our research suggests that leaded gasoline causes higher concentrations of lead accumulation in soil along populated roadways.

While many studies, like Filippelli et al. (2005)³⁰, have examined urban regions with gasoline-attributable lead concentrations along freeways, little has been done to examine heavily trafficked rural Vermont roads. The primary objective is to highlight previously unrealized risks to houses along major roadways. Due to the limited number of roads in Vermont, small highways receive more traffic and may have a high probability of residual lead contamination. Like paint, this particulate matter settles in the top 6 centimeters of the soil and can be easily inhaled or ingested when disturbed.³¹ This geographic predisposition to increased traffic along Vermont roadways suggests increased exposure potential for homes built closer to major roads. Using conservative modelling, our predicted “Roadway Riskscape” highlights areas where homes are especially vulnerable due to close proximity to roadways, even though they are predicted to have soil lead levels under the EPA safe-soil standard.

³⁰ Filippelli, G. M., Laidlaw, M.A.S., and Latimer, J.C. 2005. Urban Lead Poisoning & Medical Geology. *American Geological Society* 15(1): 4-11.

³¹ Motto, L., Daines H., Chilko M., and Motto K. 1970. “Lead in Soils and Plants: Its Relation to Traffic Volume and Proximity to Highways.” *Environmental Science & Technology*. 4(3): 231–37.

Our geo-analytical framework focuses on possible lead concentration along larger Vermont roadways to predict risk for homeowners. While other historical land uses, such as pre-1978 housing stock, orchards, shooting ranges and industrial facilities contribute to mappable locations of high risk, we chose to focus on roads as data are widespread and publicly available. We isolated all homes within 50 meters of more heavily used roads across the entire state of Vermont, ignoring smaller emergency roads. Using modeled data of the risk-zone of lead deposition near roadways from a study at Purdue University, we conservatively estimated that the amount of lead accumulation in soil around all homes located 50 meters or less from roads could be up to 250 ppm (Figure 3).³² While each of these residential buildings were individually analyzed for their proximity to roads, we have chosen to visualize roads with densities of higher risk homes.

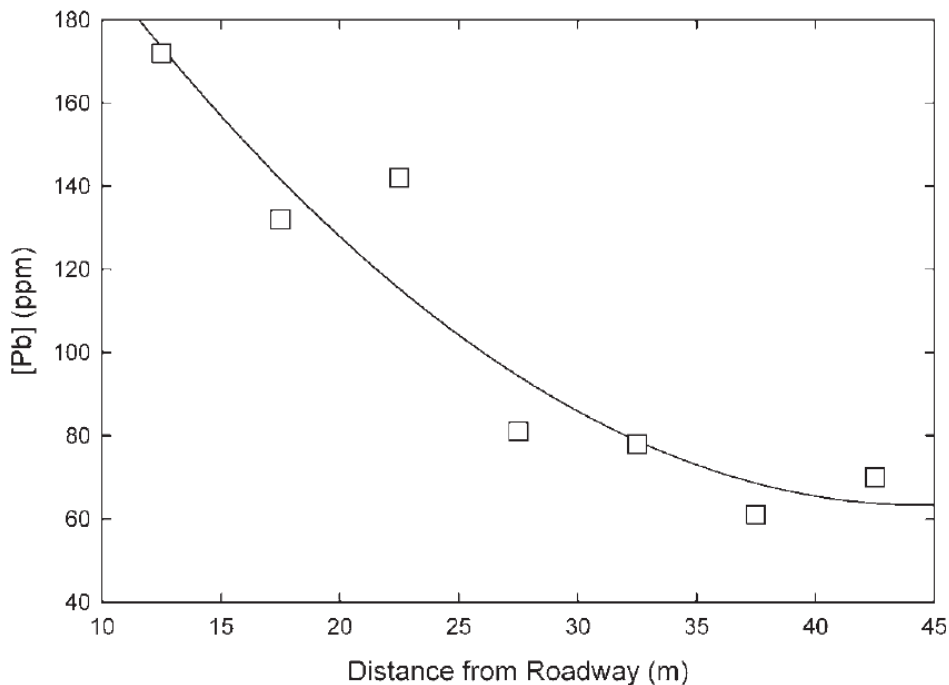


Figure 3. Roadway contamination measured in meter distance up to 200 ppm. Reproduced from Filippelli et al. 2005.

³² Filippelli, et al. 2005.

2.3 Maps

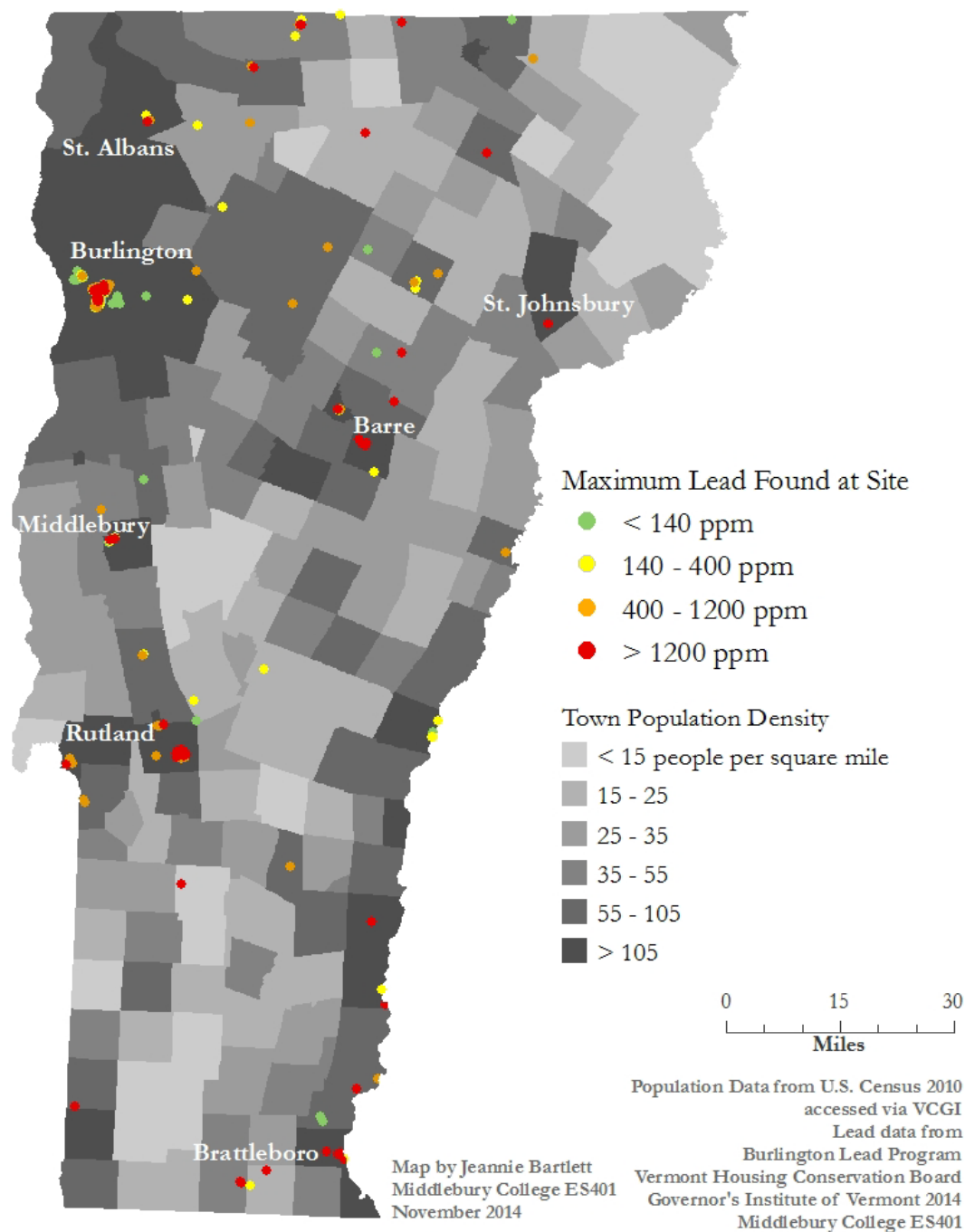


Figure 4. Dangerous levels of lead contamination in VT soils. Soils across VT are contaminated by leaded paint and gasoline. Samples are representative of individual sites, not regions. 140 ppm is the threshold for residential soils in Canada. 400 ppm is the U.S. EPA threshold for play areas and gardens. 1200 ppm is the U.S. EPA threshold for general yards. EPA standards come from the final 2001 rule in the Toxic Substances Control Act.³³

³³ Environmental Protection Agency. 2001. *Lead; Identification of Dangerous Levels of Lead*. (OPPTS--62156H; FRL--6763-5). Washington, D.C. Federal Register 66(4):1206-1240.

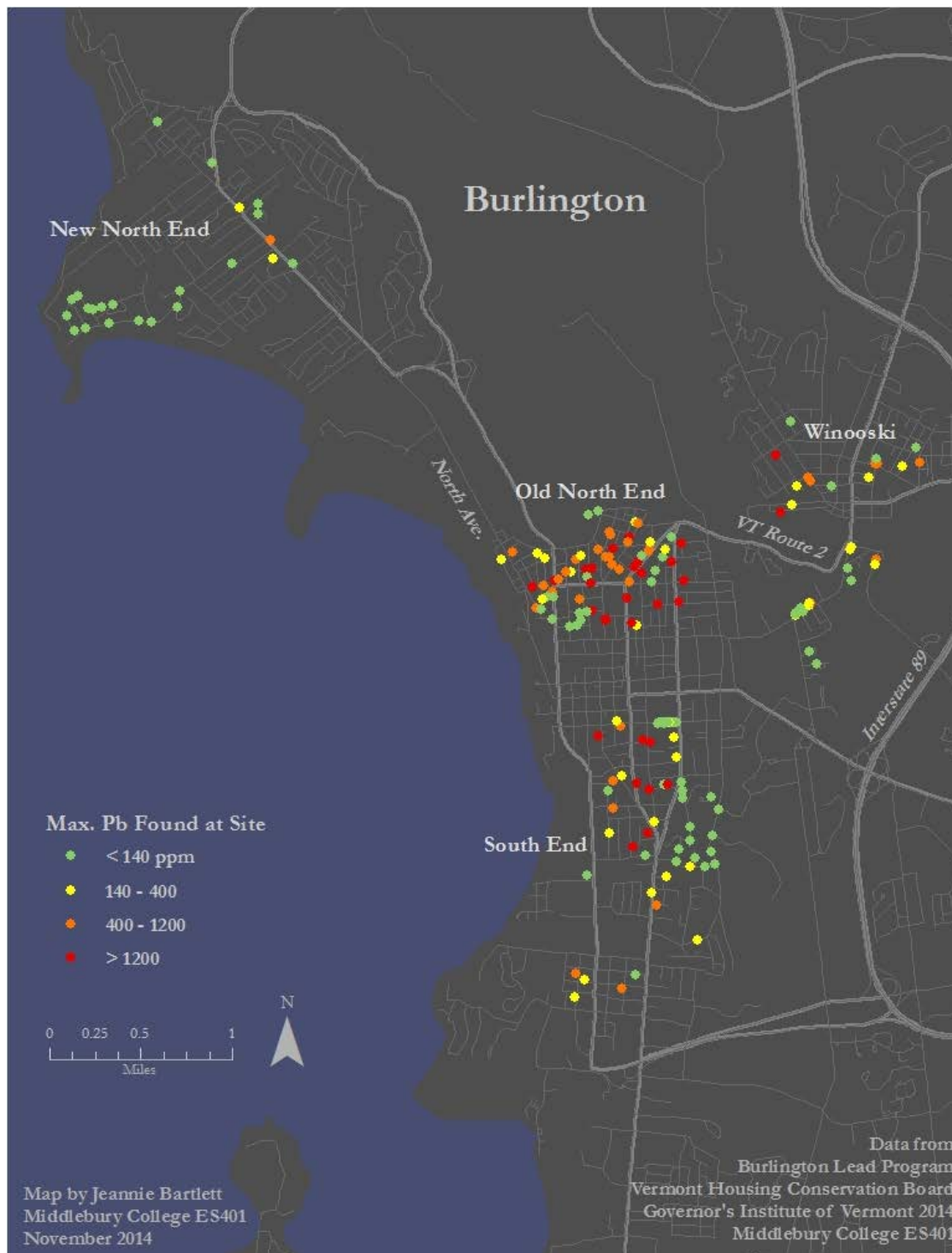


Figure 5. Unequal distributions of lead contamination in Burlington soils. Soils across Burlington are contaminated by leaded paint and gasoline. Samples are representative of individual sites, not regions. 140 ppm is the threshold for residential soils in Canada. 400 ppm is the U.S. EPA threshold for play areas and gardens. 1200 ppm is the U.S. EPA threshold for general yards. EPA standards come from the final 2001 rule in the Toxic Substances Control Act.³⁴

³⁴ Ibid.

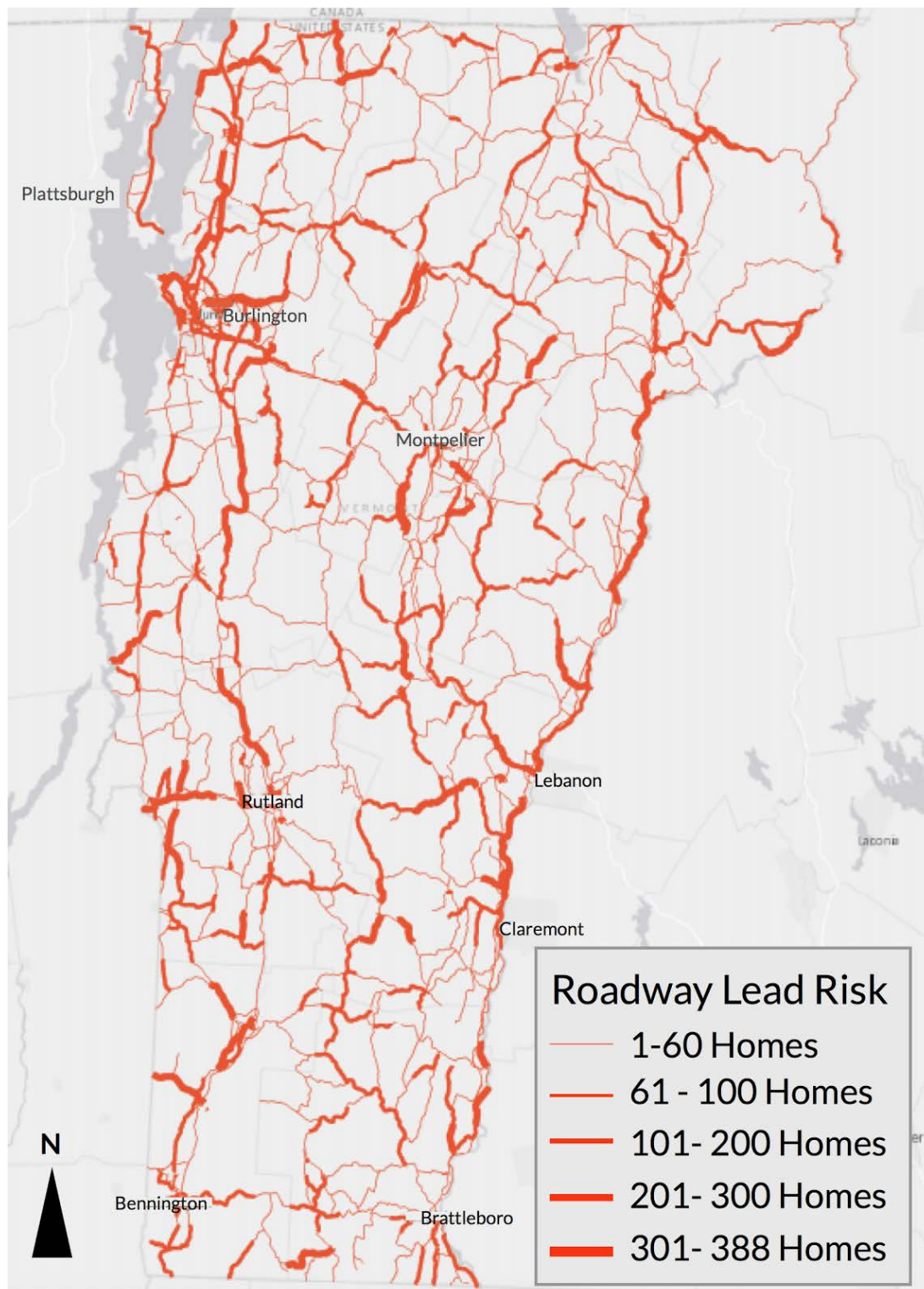


Figure 6. Geographic analysis highlighting concentrations of homes built within predicted 50 meter risk-zone of major roads in Vermont. Roads with higher number of homes should be given higher priority for soil testing to prevent possible exposure.

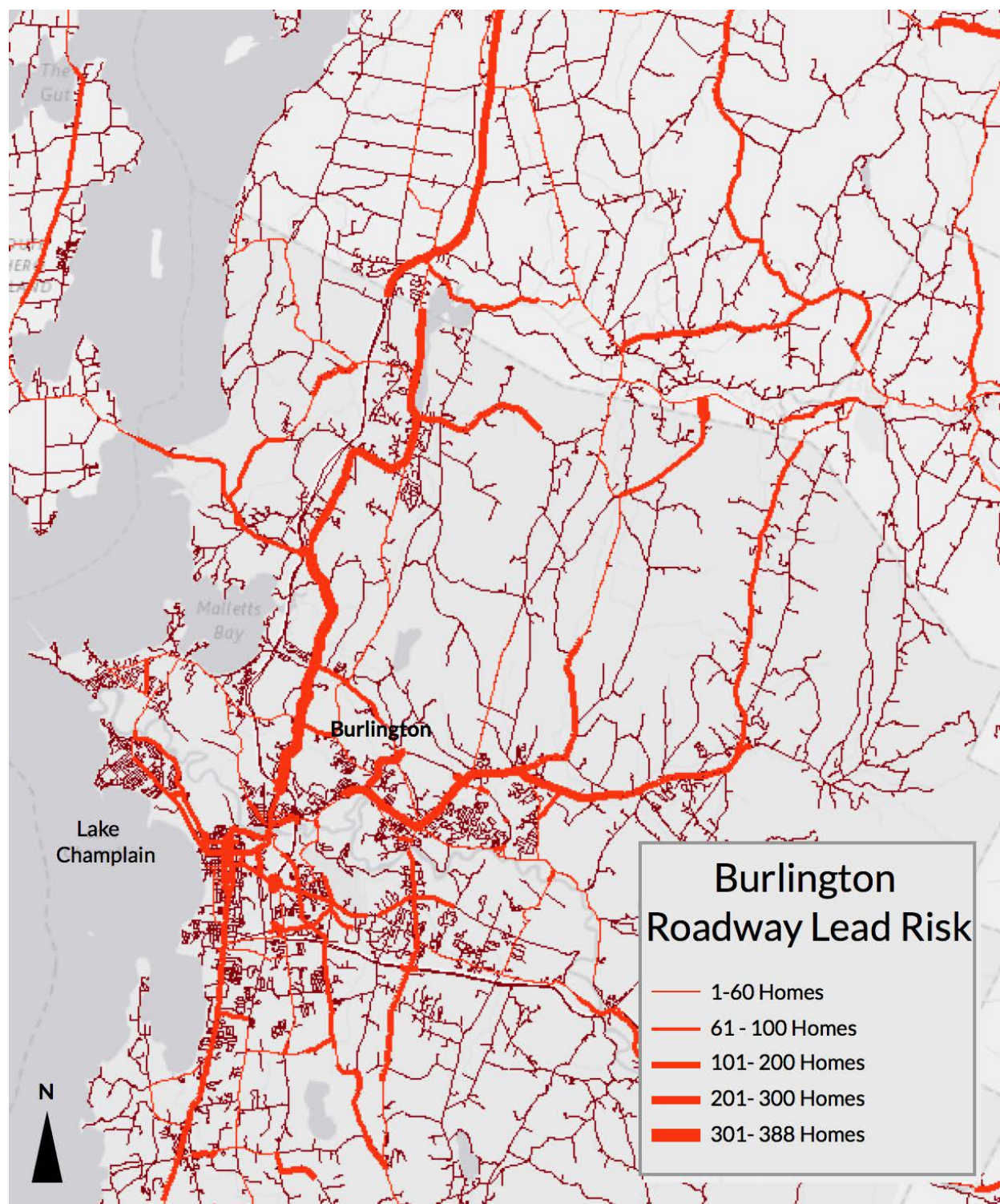


Figure 7. Higher risk of soil lead concentrations is correlated to transit corridors, specifically from New Hampshire to Vermont and the Burlington area (shown above) towards Montreal, Canada.

2.4 Discussion

The spatial distribution of known contaminated soils in Vermont (Figure 4) shows that dangerous levels of lead contamination exist in soils across the state. There is no major area of the state that does not have homes with soil lead levels above 1200 ppm. It is important to remember when viewing this map, however, that it does not display a representative sample of residential yards. The statewide map shows existing data collected by various organizations, many of which collected soil data as a follow-up to determine the cause for an elevated BLL case, biasing the data towards higher soil lead levels. The display of the map also layers points with higher lead levels over those with lower levels, prioritizing display of high-lead locations but covering some locations that have low levels.

The zoomed-in map of Burlington addresses the problem of overlapping points in the display (Figure 5). Whereas in the statewide map Burlington appears to be a tight aggregation of mostly red points, the zoomed-in city map reveals spatial heterogeneity. The Old North End has many locations with soil lead levels above 400 and 1200 ppm, whereas in the New North End almost every tested location is below 140 ppm. This difference is likely due to the different ages of the housing stock; as their names suggest, the Old North End and downtown Burlington were built decades or more ago, whereas the New North End was built much more recently. The Old North End and downtown also have longer histories of traffic than the New North End, so leaded gasoline emissions could also contribute to the higher lead levels there.

Our “riskscape” analysis of homes built close to major roads suggests a number of clustered patterns across the state. This predictive base-layer indicates where historical risks may still exist in soils near major roads (Figures 6 and 7). Since this contamination varies with difference in traffic, these points highlight regions that may require particular attention by public health organizations (Figures 6 and 7). Instead of individually testing homes, we hope that this map will help to prioritize disproportionately high risk roads with larger number of homes for testing. Furthermore, we hope that this consolidated information can inform gaps in existing data and contextualize public policy design and soil testing priorities using data-driven geographic information technologies.

We have created all of these layers using ArcGIS, the standard GIS program for the VDH and other lead programs such as the VHCB and the BLP, and the datasets are formatted as easily exportable KML files. We hope that our maps serve to highlight areas where lead soil risk may necessitate further testing or interventions based on what can be learned from the existing datasets. We recommend keeping this information as part of an open source resource for organizations studying issues of lead contamination in soil around the state to continue contribution of datasets and base-layers. Additionally, we have included our operations for creating our predictive “riskscape” model for collaborative improvement and accuracy (see Appendix A.1). It is our hope that the visualization of these data may be of benefit to all organizations hoping to reduce the risks associated with lead in soils at the residential level.

3. Drip Zone Analysis

3.1. Introduction

A large-scale geographic understanding of soil lead contamination in Vermont is important for efficient allocation of public health resources across the state. For the average Vermont family, however, this information is less useful. Without the guarantee that all locations within low-risk areas are lead-safe, or without the ability or desire to move to a lower-risk area, Vermont families need practical, inexpensive solutions that can be carried out at the household scale to avoid lead exposure before it occurs.

Home- and garden-scale solutions are best informed by soil lead testing at multiple locations around each home. However, testing on this scale is impractical at this time since current free testing services focus almost exclusively on soils around houses of individuals with elevated blood lead levels. Homeowners can independently order soil lead tests, but the high price (upwards of \$50)³⁵ can be a disincentive to testing when there is no known problem. We hope that the data and analysis presented here can be used as a tool to inform proactive, rather than reactive, practices to avoid residential soil lead exposure.

With this goal in mind, our drip zone study sought to understand the extent and patterns of soil lead contamination around lead-painted structures, and operationalize this understanding by developing a set of best management practices for lawn and garden maintenance and design. These principles seek to provide Vermont families with inexpensive and easy at-home solutions to limit lead exposure regardless of their access to soil lead testing or expensive remediation.

3.2. Methods

To determine the extent of contaminated drip zones around lead painted houses or other structures, soil samples were taken in a total of 9 transects from 6 houses in the Middlebury, Vermont area. All houses sampled were built prior to the 1978 lead paint ban, and are currently, or were known to have been, lead painted. Each transect consisted of 11 points located every 30 cm from the wall edge (0 cm) to 300 cm from the wall. The 300 cm maximum distance is in accordance with EPA drip zone sampling methodology.³⁶

A Thermo Scientific (Waltham, MA, USA) Niton XLp 706A X-Ray Fluorescence analyzer (Niton XRF) was used to assess soil lead content within the top 5 cm of soil using the Bulk Soil Analysis mode (30 source seconds, approximately 2 minutes/sample). Due to time constraints, readings for 6 transects were taken in situ while the remaining 3 were taken from bagged samples at field moisture. In cases where imported gravel was present on the soil surface, sampling took place below the gravel. Three (3) samples in each of 2 transects were unable to be taken due to paved sidewalks obstructing access to soil.

Bagged samples taken from 2 transects (N=22) were analyzed using two additional methods. First, samples were dried, ground with a mortar and pestle, sieved and re-analyzed with the Niton XRF analyzer. This method allowed us to obtain a more accurate assessment of soil lead levels by taking readings on dried and homogenized samples. The moist, un-homogenized soil samples in the original analysis may have contained paint chips or soil aggregations that may have resulted in falsely high or low soil lead readings. Second,

³⁵ Haugen, Andrea. 2014. Healthy Homes Lead Poisoning Prevention Program Manager, Vermont Department of Health. Personal Communication.

³⁶ Black & Veatch Special Projects Corp. 2006. Final Drip Zone Width Study: Omaha Lead Site. Prepared for U.S. Environmental Protection Agency.

samples were subjected to Graphite Furnace Atomic Absorption Spectrometry (GFAAS) by Middlebury College's Chemistry 0311 class. Approximately 0.1-0.15 g of sample were digested in 2.5 mL of concentrated nitric acid at 160 °C for 6 hours. Digested samples were diluted to 10-100 ppb based on Niton XRF data, and lead concentrations were determined using a PerkinElmer AAnalyst 600 (Waltham, MA, USA) graphite furnace atomic absorption spectrophotometer. Sample readings were compared to a calibration curve based on standard samples at 0, 10, 25, 50, 75, and 100 ppb. This method gave a further degree of accuracy than either set of Niton XRF readings. The two additional sets of readings from these two transects (Niton XRF readings from dry samples and GFAAS) were compared using paired t-tests to assess the degree of inaccuracy of the in situ data used to quantify the drip zone.

For the sake of consistency, only data from the in situ or field moisture bagged samples were used for analysis. Analysis was done in R (v3.0.2).³⁷ Soil lead levels were log-normally distributed (Kolmogorov-Smirnov test, $p=0.121$), and the relationship between lead level and distance from the wall was clearly non-linear. For these reasons a standard linear regression based on a normal distribution would be inappropriate. We instead fit a negative exponential model using maximum-likelihood inference. The selected model was:

$$SLL \sim \log \text{ normal} (\text{mean} = a * \exp(-b * \text{distance}))$$

where SLL refers to soil lead level, a and b are fit parameters, and distance refers to the distance from the wall at which each sample was taken. The model was optimized using the ``mle2()`` command in the ``bbmle`` package.³⁸ A discussion of this technique is provided in Bolker (2008).³⁹

Upper confidence intervals at 95%, 90%, and 75% were calculated from the optimized model. Using these confidence intervals, the minimum distances at which soil lead levels are predicted to fall below 400 ppm (the EPA⁴⁰ and Vermont State⁴¹ standard for play areas and gardens), and 140 ppm (the Canadian standard for residential soils⁴²) were determined. These values were chosen to bracket a range of soil lead concentrations that may be of particular interest or relevance to homeowners, public health officials, or policy makers.

3.3. Results and Figures

The Niton XRF readings from the field or bagged samples were not significantly different from the dry, homogenized XRF readings (paired t-test, $p=0.07$) or GFAAS results (paired t-test, $p=0.19$). We are therefore justified in using the field and bagged sample results in our model. If anything, these data, by virtue of their greater variability, resulted in a model that overestimates the width of the contaminated drip zone. The insignificant difference between these data sets, however, indicate that the discrepancy between methods is small.

³⁷ R Core Team. 2013. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. <<http://www.R-project.org/>>

³⁸ Ben Bolker and R Development Core Team. 2014. `bbmle`: Tools for general maximum likelihood estimation. R package version 1.0.16. <<http://CRAN.R-project.org/package=bbmle>>

³⁹ Bolker, Ben. 2008. *Ecological Models and Data* in R. Princeton University Press. Princeton, NJ, USA.

⁴⁰ United States Environmental Protection Agency. 2001. Lead; Identification of Dangerous Levels of Lead. *Federal Register*. 66(4):1206-1240.

⁴¹ Vermont Department of Health. 2014. Lead in Soil. Accessed Nov. 6th, 2014. <http://healthvermont.gov/enviro/lead/lead_soil.aspx>

⁴² Canadian Council of Ministers of the Environment. 2007. Soil Quality Guidelines for the Protection of Environmental and Human Health: Summary Tables.

Despite using a relatively small sample size as a result of time limitations on data collection, a drip zone effect on surface soil lead contamination in lawns was clearly seen (Figure 8). Highest lead levels were observed nearest to lead-painted walls, while more distant locations exhibited lower lead levels. It is also worth noting that soil lead levels near walls varied greatly between different houses (Figure 8).

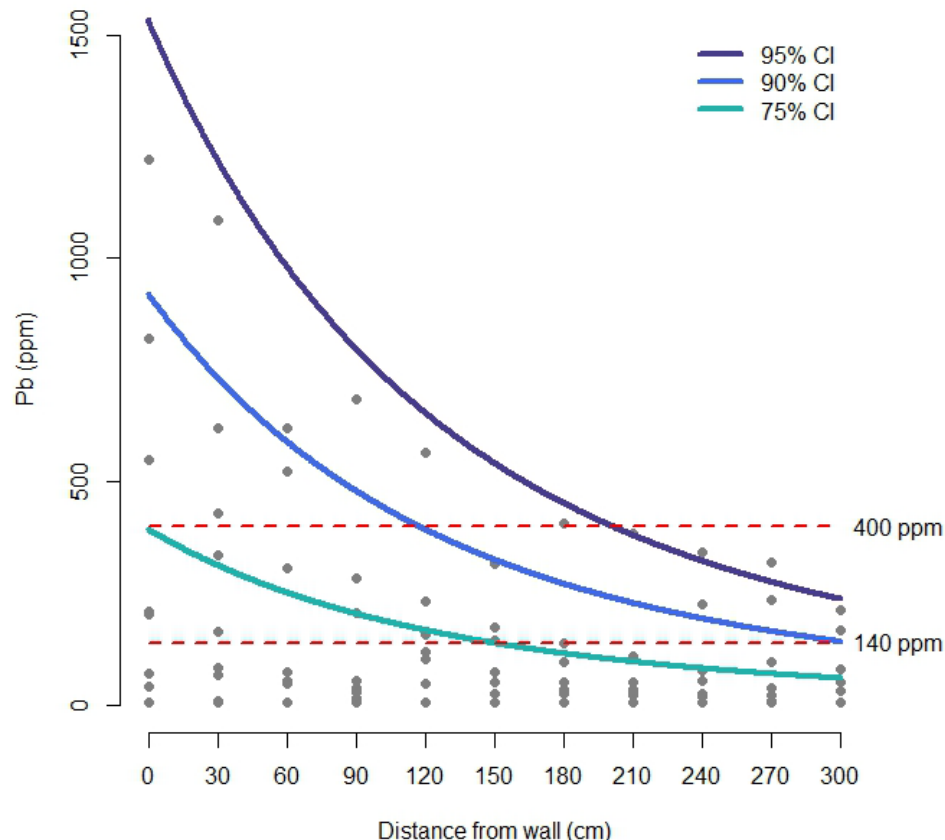


Figure 8. Drip zone lead contamination in lawn surface soils. Samples (N=93) were taken from Middlebury, Vermont area houses which had been or were currently lead painted. All samples were taken from the top 5cm of the soils.

In 95% of cases (95% confidence interval), lead levels in lawn soils are expected to fall below 400 ppm at 202 cm (6.6ft) from the wall. In 90% of cases, lead levels are predicted to fall below 400 ppm at 118 cm (3.9ft) from the wall. In 75% of cases, lead levels are expected to be below 400 ppm at the wall, and below 140 ppm at about 150 cm (4.9ft). In 10% of cases, lead levels are not expected to fall below 140 ppm even at 300 cm (9.8ft) from the wall, and in 5% of cases, they are not expected to fall below 400 ppm even at this distance. Table 1 summarizes these results.

Table 1. Distances from exterior walls at which soil lead levels are predicted to fall below threshold values. Data is taken from the model presented in Figure 8.

Threshold	Confidence level		
	75%	90%	95%
140 ppm	150 cm	>300 cm	>300 cm
400 ppm	0 cm	118 cm	202 cm

3.4. Discussion

The results presented above clearly show that soil lead contamination is highest near the house and tapers downward with distance. This pattern is consistent with our understanding of soil lead contamination resulting from chipping paint falling or washing off the sides of houses and into the soil. This pattern is not consistent with the more even soil lead contamination patterns observed in more urban areas as a result of historical leaded gasoline emissions.⁴³

The difference between rural and urban soil lead contamination patterns highlights a potential weakness of our drip zone data set. Due to all samples being taken in Middlebury, we are confident in our understanding of drip zones in rural or small town settings, but are unsure of how well the observed patterns translate to Vermont's larger cities such as Burlington or Rutland where lead from automobile emissions is likely to be more substantial. That said, over 60% of Vermont residents live in rural areas,⁴⁴ and therefore the insights from this analysis are relevant to much of the state. In the case that this analysis has underestimated the degree of soil lead contamination in more urban areas, the recommendations outlined below will not be as effective in preventing soil lead exposure. Our suggestions will still help mitigate soil lead exposure in many cases, however. The findings presented in Section 2. Geographic Analysis helps to highlight regions in which gasoline emission-sourced lead is likely to outweigh or exacerbate paint-sourced lead contamination.

The existence of a localized high-risk zone immediately around the house presents the opportunity for easy mitigation practices. Primarily, we recommend siting gardens and play areas at least 7ft (approximately 213 cm) from houses or other painted structures built prior to 1978 in order to significantly reduce the risk of exposure to contaminated soils. Though drip zones are commonly conceptualized as a band around the house that is sharply delineated from the surrounding lawn, our data show a much more gradual decline in soil lead levels with no clear distance beyond which contamination risk is non-existent. Our baseline recommendation of 7ft (approximately 213 cm) aligns with the EPA and Vermont state standard of 400 ppm lead in play area soils, but poisoning cases have occurred in Vermont as a result of soils with lead levels well below this threshold.⁴⁵ For this reason, we suggest that gardens be sited as far from lead-painted, or previously lead-painted, structures as reasonably possible.

Beyond siting gardens away from houses, gardeners should be aware of the potential dangers of exposed garden soil. Wind-borne soil dust as a result of dry conditions can travel between lawns in more densely populated areas, and can enter houses through screens. Simple

⁴³ Brabander, Dan. 2014. Professor of Geosciences, Wellesley College. Personal communication.

⁴⁴ Public Information Office. 2012. Growth in Urban Population Outpaces Rest of Nation, Census Bureau Reports. *US Census Bureau*. Accessed Nov. 7th, 2014.

<https://www.census.gov/newsroom/releases/archives/2010_census/cb12-50.html>

⁴⁵ Andrea Haugen, Healthy Homes Lead Poisoning Prevention Program Manager, Vermont Department of Health, personal communication.

garden maintenance practices such as regular watering or mulching with lead-free compost can effectively eliminate this as an exposure pathway.

For those who are working or playing directly in the soil, the dirt carried by shoes, clothing, and hands can be a significant lead exposure pathway. This soil can easily become dust in the home, and small children can ingest dust or soil through hand to mouth behaviors. Simple habits such as wearing gloves while gardening, thoroughly wiping or removing shoes before entering the home, and regularly cleaning the floor and porch around the door can easily reduce the amount of potentially leaded soil dust in the home. Small children are particularly vulnerable to lead exposure because of their body size and their tendency for hand-to-mouth behaviors. Children should be monitored and taught to thoroughly wash their hands to prevent accidental ingestion of potentially contaminated soil. This is not to say that children should avoid playing outside. The health benefits of active, outdoor play are well known, and gardening is a great way for parents and children to spend time together. Thus, we recommend awareness and caution, not fear and avoidance, for outdoor work and play activities.

If only decorative plants are being grown, exposure as a result of garden products is not a concern. However, for those consuming vegetables grown in untested soil, ingestion of lead can be a substantial problem. Proper cleaning and preparation of home-grown foods can reduce this risk. Fruiting vegetables such as tomatoes, beans, or peppers do not easily take up lead from the soil.⁴⁶ Therefore, nearly all of the lead content they may have is a result of soil dust from the surrounding garden. Thoroughly washing vegetables prior to consumption reduces the risk of ingesting this soil. Leafy vegetables such as cabbage, chard, or parsley take up lead from the soil more easily than fruiting vegetables, but only at soil lead levels greater than 400 ppm.⁴⁷ Siting gardens more than 7ft (approximately 213 cm) from houses or other painted structures and thoroughly washing garden produce can therefore reduce this risk. Belowground vegetables such as carrots, onions, or radishes are more risky because of their direct contact with soil.⁴⁸ This results in increased soil on the surface of the vegetable, and increased absorption by the edible portion of the plant.⁴⁹ These vegetables should be thoroughly washed and peeled before consumption to reduce this risk, and never grown near houses or other painted structures. If high lead levels are suspected and confirmation through soil testing is not possible, these vegetables should not be grown.

None of the above information is intended to discourage the consumption of fresh, home-grown vegetables. The nutritional benefits of doing so, while outside of the scope of this report, are indisputable for both adults and children. The results of our drip zone study and the results of Finster, et al.⁵⁰ suggest that with the adoption of a few basic precautions, lead exposure from garden soils can be virtually eliminated.

⁴⁶ Finster, M.E., K.A. Gray, and H.J. Binns. 2004. Lead levels of edibles grown in contaminated residential soils: a field survey. *Science of the Total Environment*. 320: 245-257.

⁴⁷ Ibid.

⁴⁸ Ibid.

⁴⁹ Ibid.

⁵⁰ Ibid.

4. Public Outreach

4.1. Introduction

Communicating the dangers of lead in soil is an important step in decreasing lead exposure in Vermont. Without effective communication and public outreach, our findings and recommendations will go unheard and unheeded. We created outreach materials that incorporate the insights gained from our drip zone study and lead-safe yard management practices from existing literature. Defining our audience is the first step in effective outreach. The main audience we hope to reach and inform about the dangers of lead in soil is homeowners with yards and children. This is a vast and diverse group and thus we must work through large and influential organizations to reach as many people as possible. The VDH is one such organization tasked with sharing information with Vermont's citizens about possible health dangers. With the rate of lead poisoning from soil on the rise, VDH identified a need for more soil-related lead outreach and educational materials.⁵¹ Andrea Haugen from the VDH expressed interest in having us create informational outreach materials for the HHLPPP to distribute. We created a tri-fold pamphlet and web-based material that the HHLPPP, along with other interested organizations, can use to inform Vermonters about the dangers of soil lead contamination.

4.2. Creating Effective Outreach Materials

Many organizations and state health departments have created outreach materials to educate the public about the dangers of lead in soil. The VDH is no exception, though they recognized that their materials needed some key content and components to engage their audience.⁵² We hope that our outreach material will help meet those needs so that the VDH can more effectively provide information about the dangers of lead in soil.

There is a wide body of psychological and health communication literature that describes how to effectively reach people. We combined this knowledge with existing soil lead outreach material from various organizations and Departments of Health from other states to create content that both reaches our audience and provides useful and accurate information regarding soil-lead dangers and yard management.

We took into account how the audience will receive and interpret the outreach material to ensure that the message is understood. When trying to reach a broad audience with written information it can be challenging to not cognitively overwhelm the reader, keep their attention, and impact them enough to elicit behavior change. Our decisions and strategies in designing our outreach materials are discussed below.

We used both text and related images which allow readers to use two different areas of their brain to process what is being conveyed. This creates a richer learning experience by increasing the reader's working memory capacity, thus improving the likelihood that the information will stick with the audience.⁵³ At the same time, if not used appropriately, images can negatively impact the audience's ability to understand information. Images that are not easily associated or related to the text, in both content and placement, distract from overall learning.⁵⁴

⁵¹ Haugen, Andrea. 2014. Healthy Homes Lead Poisoning Prevention Program Manager, Vermont Department of Health. Personal Communication.

⁵² Ibid.

⁵³ Cook, M. 2006. Visual representations in science education: the influence of prior knowledge and cognitive load theory on instructional design principles. *Wiley InterScience*. 90:

⁵⁴ Wu, H.-K., and Shah, P. 2004. Exploring visuospatial thinking in chemistry learning. *Science Education*, 88: 456-492

We created outreach materials that feature spatially contiguous and relevant images that accompany our text. We took special attention in aligning our images in a way that provides visual consistency and facilitates a smooth flowing document. At the same time, we divided our materials into distinct sections that makes the information easier to process. In addition, the images of risky yard management and behavior are bordered in red while images of the best practices are bordered in green. Research shows that Americans naturally associate red with danger and green with safe.⁵⁵ This will help readers assess the images in our outreach material.

Holding the audience's focus is key to disseminating information.⁵⁶ We used attention-grabbing techniques to improve the understanding of our material.⁵⁷ For example, we developed a hook that draws in the audience and then convinces them to read the entirety of our materials. Our hook establishes the context for lead in soil in Vermont and explains its risk. This has the effect of inspiring a sense of fear and urgency in the reader. Then, before scaring the reader away we inform them that there are things they can do to alleviate the fear if they keep reading. If our outreach materials are effective at informing the public of the dangers of lead in soil as well as providing practical remediation strategies, then we should see the rate of soil-caused lead poisoning decrease.

4.3. Outreach Material

Below are the tri-fold pamphlet and the web-based material we created. The pamphlet is first and the web-based material comes second. Details on how to obtain higher-quality versions of these materials are available in Appendix A.3.

⁵⁵ Wogalter, M.S., V.C. Conzola & T.L. Smith-Jackson. 2002. Research-based guidelines for warning design and evaluation. *Applied Ergonomics* 33: 219–230

⁵⁶ Severtson, D. J., and Vatovec, C. 2012. The theory-based influence of map features on risk beliefs: self-reports of what is seen and understood for maps depicting and environmental health hazard. *Journal of Health Communication*. 17: 836-856

⁵⁷ Itti, L. 2007. Visual salience. *Scholarpedia*. 2(9):3327

Dangers of Lead



Children are most vulnerable and sensitive to lead. Crawling on the ground, playing in dirt, and putting objects in their mouths increases the likelihood of lead exposure. Children absorb lead more easily because of their rapid growth.

Exposure to high levels of lead can:

- ▶ Disrupt childhood development
- ▶ Damage the brain, kidneys and nervous system
- ▶ Cause learning challenges and behavior issues

The effects of lead may take years to show, and they can last a lifetime.

Lead In Soil

More Information

For More information about lead in soil, soil testing, and remediation services please call Childhood Lead Poisoning Prevention Program at the Vermont Department of Health at 1-800-439-8550 or (802)865-7786 or visit <http://healthvermont.gov/enviro/lead/>.

Lead

A Hazard in Soil



How to protect you and your family from lead-contaminated soil in your yard.

Play Areas

To make a play area lead-safe, locate it 7 feet away from any structure painted before 1978 and cover all bare soil.



- ☑ Planting thick grass is an easy way to cover bare soil. Be sure that grass is growing fully over the entire lawn; keep an eye out for any bare spots.
- ☑ In areas where grass won't grow, such as under a playset, spread wood chips, mulch, or sand. Be sure that exposed soil is covered.

Drip Zones

The drip zone is the area alongside a house extending 7 feet out. This area is at high risk of lead contamination due to flaking paint. Also, the first few feet from the house usually have a high amount of exposed soil.

- ☑ Plant thick shrubs to discourage children from playing in exposed drip zone soil.



- ☑ Cover the area with mulch or gravel. You can also place a small fence around the area.

Gardens

Gardens have a high amount of exposed soil, which could be tainted with lead. Try these tips to limit exposure to contaminated garden soil:



- ☑ Locate garden 7 feet away from structures painted before 1978.
- ☑ Put a fence around your garden to keep unsupervised children out.

- ☑ Wear gardening gloves to keep your hands clean.

- ☑ Keep soil moist to limit dust.

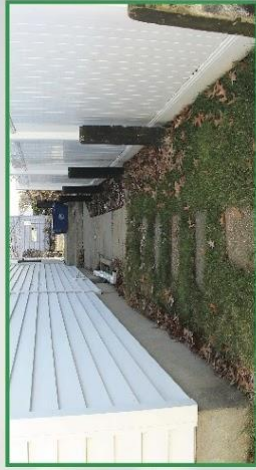
- ☑ Scrub all vegetables and peel all root vegetables to remove soil before eating.



- ☑ If your soil is contaminated, avoid growing root vegetables and leafy greens. Tomatoes, corn, squash, cucumber, eggplant and other plants that have internal seeds take up less lead.

Walkways

If you have dirt walkways, you could be tracking contaminated soil into your house. When dried out, this soil can be inhaled as dust.



- ☑ Build a brick, concrete, gravel, or stepping stone walkway to prevent bringing contaminated dirt into your house.

Other Tips

- ☑ Prevent lead from entering your home by having doormats at your home's entrances and taking off shoes before walking around your house.
- ☑ Clean floors and carpets weekly to remove any lead dust that could have accumulated.
- ☑ Wash hands often.
- ☑ Supervise children and stop them from putting dirty objects in their mouths.
- ☑ Do not let pets dig within 7 feet of your house.
- ☑ Proper nutrition can help to minimize the effects of lead if you or your child happens to be exposed. Diets with adequate calcium and iron will reduce your body's ability to absorb lead.

Lead: a Hazard in Soil



You may have heard that leaded paint is a hazard to you and your children's health, but did you know that lead in soil can also be a health hazard? Leaded paint chips and exhaust from leaded gasoline are the main soil contaminants in Vermont. While lead has been banned from paint since 1978 and gasoline since 1986, once lead enters the soil it does not wash away or biodegrade. It remains a hazard and continues to poison people



today. Because lead can persist for so long, it is hard to know if your soil is lead safe even if there are no ongoing sources of lead contamination. The only way to know if your soil is lead free is to have it tested.

Dangers of Lead Exposure

Children are most vulnerable and sensitive to lead. The Common childhood behaviors of crawling on the ground, playing in dirt, and putting objects in their mouths increases the likelihood of lead exposure. Rapid childhood growth means that lead becomes absorbed into the body at high rates.

Exposure to lead can:



- ▶ Disrupt childhood development
- ▶ Cause learning challenges and behavior issues
- ▶ Damage the brain, kidneys, and nervous system



Some of these symptoms may not become apparent until the child is older, and they can affect the rest of their life. It is important to limit lead exposure for a healthier now and healthier future.

How to Avoid Contaminated Soil

While lead is a dangerous and long-lasting contaminant, there are things you can do to limit your family's exposure to lead. In general, avoiding bare soil will decrease the likelihood of lead exposure. Lead levels tend to be highest closest to the house and decrease further from the house. At 7 feet away from the house lead is at safer levels. The following are techniques that you can do yourself to make your yard lead safe.

Play areas

To make a play area lead-safe, locate it at 7 feet away from any structure painted before 1978 and cover all bare soil.



☑ Planting Healthy and thick grass is an easy way to cover bare soil. Be sure that grass is growing fully over the entire lawn; keep an eye out for any bare spots.

☑ In areas where grass won't grow, such as under a playset, spread wood chips, mulch, or sand. Be sure that exposed soil is covered

Drip zones

The drip zone is the area alongside a house extending 7 feet out. This area is at high risk of lead contamination because years of flaking paint can end up here. In addition, the first few feet from the house usually have a high amount of exposed soil.



☑ Plant thick shrubs to discourage children from playing in any area with exposed soil.

☑ Cover the area with mulch or gravel. You can also place a small fence around the area.

Gardens

Gardens are a great way to spend time outdoors and grow food for your family. Gardens, however, have a high amount of exposed soil, which could be tainted with lead. Try these techniques to limit exposure to the potentially contaminated soil in your garden:



cc photo from flickr user Lori L. Stetson

- ☑ Locate your garden 7 feet away from painted structures that were built before 1978.
- ☑ Put a fence around your garden to keep unsupervised children out.
- ☑ Wear gardening gloves to keep your hands clean.
- ☑ Keep soil moist to limit dust.
- ☑ Scrub all vegetables and peel all root vegetables to remove soil before eating.



cc photo from flickr user Kate Tedesco



- ☑ If your soil is contaminated, avoid growing root vegetables and leafy greens. Tomatoes, corn, squash, cucumber, eggplant and other plants that have internal seeds take up less lead.

Following these gardening tips will make your gardening experience safer. To further remove the threat of lead in your garden, you can build a raised garden bed away from your house.

Walkways

Unless properly maintained, the walkways leading to your house can be a source of lead exposure. If you have a dirt walkway you could be tracking contaminated soil into your house where it can be inhaled as dust. building a brick, concrete, gravel, or stepping stone walkway will prevent you from bringing contaminated dirt into your house.




Other Tips

- ☑ Prevent lead from entering your home by having doormats at your home's entrances and taking off shoes before walking around your house.
- ☑ Clean floors and carpets weekly to remove any lead dust that could have accumulated.
- ☑ Proper nutrition can help to minimize the effects of lead if you or your child happens to be exposed. Diets with adequate calcium and iron will reduce your body's ability to absorb lead.
- ☑ Supervise children and stop them from putting dirty objects in their mouths.
- ☑ Wash hands often.
- ☑ Do not let pets dig within 7 feet of your house.

More Information

► For More information about lead in soil, soil testing, and remediation services please call Childhood Lead Poisoning Prevention Program at the Vermont Department of Health at 1-800-439-8550 or (802)865-7786

4.4 User Feedback

Reader feedback has been crucial in the development of our final products. While the theories behind creating effective and engaging materials is relatively straightforward, implementing them can be tricky. We found that after working for so long and laboring over details, we had a hard time stepping back and evaluating the products as a whole. Getting individuals with “fresh eyes” to review our product and provide feedback helped us see many big-picture issues. For example, it was brought to our attention that the spatial alignment of our broad sections, text boxes, and images made the materials seem “busy,” which detracted from the reader’s ability to take in the information. Also, the readers gave us feedback about small things like our checkmark bullet points, which they found unclear. We solved these issues by having a uniform alignment throughout our materials and changing the border of our checkmark bullets. Being open to user feedback has helped shape our materials for the better.

4.5. Further Distribution

Our outreach materials are being distributed in two different formats: A web-based informational document and a tri-fold paper pamphlet. The web-based material will be posted on the Vermont Department of Health's website. We hope that other organizations working to prevent lead contamination, such as the VHCB and the BLP, will also put this material on their website or provide a link to it. This informational document could also be useful and relevant on gardening and community websites such as Front Porch Forum, Vital Communities, Vermont Public Radio's Vermont Garden Journal, and other listservs. Tri-fold pamphlets could also be distributed at a variety of relevant locations such as health or community centers, schools, and hardware and garden stores.

5. Policy Proposals for Preventing Lead Exposure

5.1. Introduction

The Vermont Department of Health has done crucial work in preventing lead exposure and identifying and treating children who have been exposed to hazardous levels of lead. In addition to distributing outreach materials, we hope to encourage structural changes through long-term policy solutions. The problem of childhood lead contamination persists largely due to the diffuse distribution of lead contaminants in houses and soils. In cities, all soils are at risk of contamination from the use of leaded gasoline until 1996. Any house built before 1978 is likely to have lead paint, which can chip and peel thus creating a potentially hazardous environment for children inside and in the yard. Vermont has an aging housing stock which has resulted in lead contamination that cuts across regions, race, and class.⁵⁸ Vermont could further reduce childhood lead exposure by increasing funding for lead poisoning prevention and enforcement of current Vermont law.

Here we outline two policy recommendations for Vermont, listed in order of priority. First, a nominal fee of \$0.25 per gallon of paint sold should be implemented to ensure reliable funding for the Department of Health Healthy Homes Lead Poisoning Prevention Program (HHLPPP). Second, State law should mandate that insurance providers cover childhood blood lead level tests and follow-up care. There are many other potential policy solutions that would help address lead contamination in Vermont. One particularly helpful report that outlines many of these is “Reducing Lead Exposure in US Children: A Blueprint for Action” by the National Center for Healthy Housing.⁵⁹

5.2. Policy Recommendations

(a) Fee on paint sales

A small fee of \$0.25 per gallon on paint sales would improve the capacity of the HHLPPP to reach children in need and secure the department’s funding for years to come. The fee would be imposed on large manufacturers, wholesalers, and importers of paint, thus avoiding placing the burden on individual Vermont citizens who are not responsible for the use of lead paint in Vermont.

i. A need for better funding

The HHLPPP has significantly decreased high blood lead levels in Vermont through their work preventing lead exposure and helping poisoned children, and with more funding and a more consistent source of funding, they could do even more. The bulk of the HHLPPP funding currently comes from the CDC. This funding, however has not been always stable. In September 2012, the CDC lost its funding for lead poisoning prevention and cut state funding nationwide. The CDC’s funding for lead poisoning prevention could still be cut at any point. HHLPPP’s total proposed budget to the CDC was \$500,000 and they were awarded \$349,704. With the additional \$151,000, HHLPPP would have expanded their EMP education in southern Vermont. The fluctuating funding amounts and the reliance on the grant approval

⁵⁸ Haugen, Andrea. 2014. Healthy Homes Lead Poisoning Prevention Program Manager, Vermont Department of Health. Personal Communication.

⁵⁹ National Center for Healthy Housing. October 2014. “Preventing Lead Exposure in US children: A Blueprint For Action.” Accessed 7 Dec 2014.
<http://nchh.org/Portals/0/Contents/lead%20strategies_v8%20%2819%20October%202014%29.pdf>.

limits the ability of HHLPPP to engage in long-term strategies for lead poisoning; long-term funding solutions are necessary for a problem this scale and duration.⁶⁰ Vermont should proactively find funding for the Program, rather than wait for CDC funding to be cut and having to reapportion an already tight state budget.

The HHLPPP currently has one case manager who is assigned to all children with blood lead levels of 10µg/dL or higher and does a follow-up phone call for all children at 5-9µg/dL. Case managers go into the home, consult with the family, collect dust wipe and soil lead test samples, and try to identify exact causes of lead poisoning. With another case manager, the HHLPPP could visit substantially more children, even doing home visits for children with 9 µg/dL or less. Blood lead levels (BLL) as low as 2µg/dL have shown to impact the health of children.⁶¹ The sources of lead poisoning for children with levels of lead at 5-9µg/dL must be stopped quickly to minimize long-lasting health impacts.⁶²

In 2012, there were 726 children in Vermont who tested at 5-9µg/dL.⁶³ These families did not receive case management services. Without a case manager to follow-up in person and determine sources of lead poisoning at the child's home, the sources of these children's lead poisoning are less likely to be addressed. Case manager visits are particularly important in New American and refugee communities in Vermont. These communities are at a higher risk for lead poisoning and some households are non-English-speaking, which means case manager visits require a translator and more time.

Currently, Vermont's only case manager follows up with all children with a venous-confirmed blood lead level at or above 10 µg/dL. In 2012, this case manager visited the homes of 38 children for the first time and followed up with 114 families.⁶⁴ An additional case manager could be reasonably expected to visit approximately 150 homes of children. Thus, this additional case manager would help close the service gap that currently exists regarding children who tested at 5-9 µg/dL. This new case manager could call the families of children who got a capillary test between 5-9 µg/dL and visit those who had a venous confirmation between 5-9 µg/dL. Ideally, every child with any significant blood lead poisoning would receive a follow-up visit, which would require hiring several additional case managers. The HHLPPP could determine which children were least likely to receive proper follow-up care and lead poisoning source remediation and allocate the second case manager to help them. If additional state funding became available or if the fee per gallon of paint was raised, three additional case managers could be hired. The cost per additional case manager is roughly \$100,000, so the total increase in budget to hire three more case managers would be \$300,000. If the CDC funding continues alongside the new paint tax revenue, the HHLPPP's total budget would increase to \$793,250. This would cover the HHLPPP's existing services and the hiring of three additional case managers.

⁶⁰ Haugen, Andrea. 2014. Healthy Homes Lead Poisoning Prevention Program Manager, Vermont Department of Health. Personal Communication.

⁶¹ Canfield R.L., C.R. Henderson, D.A. Cory-Slechta, C. Cox, T.A. Jusko, B.P. Lanphear. 2013. "Intellectual impairment of children with blood lead concentrations below 10 µg per deciliter." *New England Journal of Medicine*: 348. <<http://www.nejm.org/doi/full/10.1056/NEJMoa02284>>.

⁶² Haugen, Andrea. 2014. Healthy Homes Lead Poisoning Prevention Program Manager, Vermont Department of Health. Personal Communication.

⁶³ Ibid.

⁶⁴ Haugen, Andrea. 2013. "2012 Annual Report on Childhood Lead Poisoning Prevention." <http://healthvermont.gov/admin/legislature/documents/ChildhoodLeadPoisoning_LegislativeRpt_041513.pdf>.

ii. Precedent for a paint fee

Maine's Lead Poisoning Prevention Program is very similar to Vermont's HHLPPP. Maine currently has a fee of \$0.25 per gallon of paint.⁶⁵ It directly funds the Lead Poisoning Prevention Fund, which provides for Maine's lead testing program. The fee also allows an exemption for businesses who sell less than 1800 gallons of paint per year, keeping the law from harming small businesses and contractors. We propose that the Vermont law include a similar exception for affected merchants with less than 1800 gallons of yearly sales. This would avoid placing an unnecessary burden on small business owners who are central to Vermont's economy.

Many of the same companies that sold lead paint are still selling paint. In California in 2013, three paint manufacturers lost a public nuisance case that resulted in the award of \$1.1 billion, most of which helped fund lead poisoning prevention programs like the HHLPPP. Even before then, in 1991 the California Childhood Lead Poisoning Prevention Act "assessed a fee on companies who had significantly contributed historically to environmental lead contamination," particularly the paint and gasoline industry.⁶⁶ Thus it is economically and morally consistent under extended producer responsibility for the state to charge paint companies for their past externalities that are still harming children today.

iii. Current Vermont paint fee structure and implementation of new fee

Vermont recently implemented a fee on paint for paint recycling by passing Act 58 in June 2013.⁶⁷ This was supported by an industry lobbying group and PaintCare, a nonprofit that runs paint recycling programs, who recommended placing a \$0.75 fee on every gallon and a \$1.60 fee on one to five gallon containers.⁶⁸ This fee is levied at the cash register, and thus it is a direct increase in the cost of paint to consumers. The program is set up so that the industry must calculate what the cost is to run the program and then figure out the fee and have it audited. The only mandatory cost is a \$15,000 fee to the Agency of Natural Resources (ANR). They estimate that this \$0.75 fee will raise \$1.1 million every year for the paint recycling program.⁶⁹ This was a significant expansion of paint collection and recycling in Vermont, as according to ANR it previously "cost Vermont municipalities about \$227,000 per year to manage the collection of leftover paint."⁷⁰ This was a small portion of leftover household paint, as most paint never made it back to the few municipal recycling centers before the new program started.

The law implementing the fee on paint sales would explicitly mandate that the paint companies could not pass on the costs to consumers by including a clause. This is a common strategy when enforcing civil penalties against companies, though in practice it is impossible to avoid some portion of the cost eventually being passed on to consumers. This is in contrast with the current VT paint recycling fee law, which mandates that the fee is paid by the consumer at

⁶⁵ State of Maine. 2014. *Lead Poisoning Prevention Fee Rules*. <<http://www.maine.gov/dhhs/mecdc/environmental-health/eohp/lead/documents/lpprules.pdf>>.

⁶⁶ San Francisco City Attorney's Office. 2013. "Lead Paint Litigation: Timeline of Events." <<http://sfcityattorney.org/modules/showdocument.aspx?documentid=1322>>.

⁶⁷ General Assembly of the State of Vermont. 2013. *No. 58. An Act relating to establishing a program for the collection and recycling of paint*. <http://www.anr.state.vt.us/dec/wastediv/HHW/documents/ACT058.pdf>

⁶⁸ PaintCare. 2014. "How will the Vermont Paint Stewardship Program Affect Paint Retailers?" <<http://www.paintcare.org/wp-content/uploads/docs/vt-factsheet-retailer.pdf>>.

⁶⁹ Bernardo, Valerie, et al. 2014. "PaintCare: Vermont Architectural Paint Stewardship Program Plan." January 24, 2014. PaintCare, Inc. pg 34. <<http://www.anr.state.vt.us/dec/wastediv/solid/documents/RevisedPaintCareVTPlan01.24.2014.pdf>>.

⁷⁰ Vermont Agency of Natural Resources. 2013. "Paint Product Stewardship Law- Act 58." <http://www.anr.state.vt.us/dec/wastediv/HHW/documents/PaintSummaryMR_8_14_13.pdf>.

the cash register. The fee proposed here is not assessed on the consumer but instead on manufacturers and wholesalers and thus is collected upstream, reducing administrative costs and impact on consumers. This minimizes the effect on individual Vermonters and avoids charging consumers for a problem they did not cause. Vermont law should explicitly name who pays the tax, drawing from the precedent of Maine's law:

- “1. The manufacturer of the paint which offers for sale, sells, or distributes the product under its own brand label in Maine;
2. The brand label owner of the paint which is sold or distributed in Maine, if the manufacturer does not sell or distribute the paint under its own brand label in Maine;
3. The importer of the paint into Maine, if neither of the above applies.”⁷¹

iv. Economic impact of a fee on paint sales

To calculate the economic impact of a fee on paint sales, we need the estimated number of gallons of paint sold per year. The paint industry will record and report these numbers as part of the paint recycling program, so there will not necessarily be an additional cost for calculating gallons of paint sold.

Every year, roughly 1.777 million gallons of paint are sold in Vermont, according to a policy brief filed in support of the paint recycling program fee.⁷² With the proposed fee of \$0.25 per gallon, this would result in an approximate revenue of \$444,250 per year (assuming perfect inelasticity). Because this cost would be placed on paint producers, wholesalers, and importers by mandate, the cost to Vermonters would be significantly less than the total revenue.

(b) Mandatory insurance coverage

Public and private healthcare providers should be required to cover the lead blood tests of children that are currently mandated by law. In 2008, the Legislature updated the Vermont Lead Law and added the following clause (§ 1755.b.):

“Annually, the Commissioner shall determine the percentage of children six years of age or younger who are being screened in accordance with the guidelines. If fewer than 85 percent of one-year-olds and fewer than 75 percent of two-year-olds as specified in the guidelines are receiving screening, the Secretary shall adopt rules to require that all health care providers who provide primary medical care to young children shall ensure that their patients are screened and tested according to the guidelines, beginning January 1, 2011.”

The Department of Health HHLPPP currently tests 80.3% of one-year-olds and 69.1% of two-year-olds.⁷³ Testing rates are quite high in VT compared to adjacent states. For example, only 53% of children in New Hampshire between the ages of one and two were tested in 2012.⁷⁴

⁷¹ State of Maine. 2014. *Lead Poisoning Prevention Fee Rules*. <<http://www.maine.gov/dhhs/mecdc/environmental-health/eohp/lead/documents/lpprules.pdf>>.

⁷² Bernardo, Valerie, et al. 2014. “PaintCare: Vermont Architectural Paint Stewardship Program Plan.” January 24, 2014. PaintCare, Inc. pg 34.
<<http://www.anr.state.vt.us/dec/wastediv/solid/documents/RevisedPaintCareVTPlan01.24.2014.pdf>>.

⁷³ Haugen, Andrea. 2014. Healthy Homes Lead Poisoning Prevention Program Manager, Vermont Department of Health. Personal Communication.

⁷⁴ Fleisher, Chris. 2013. “Lead Testing of Children Varies Greatly by State in Northeast.” *Valley News*. 29 December 2013. <<http://www.vnews.com/news/9883170-95/lead-testing-of-children-varies-greatly-by-state-in-northeast>>.

VT's testing rate still falls short of the law's ambitious goal of 85% and 75%, invoking the mandatory universal testing clause that states that all health care providers must test the blood lead levels of young patients. This means that every 1 and 2 year old in the state of Vermont is currently required by law to have a blood lead test.

Insurance coverage for mandatory blood lead testing and follow-up care is not universally guaranteed. This could be a contributing factor to noncompliance with current lead testing. Vermont relies on insurance companies to voluntarily cover blood lead tests and treatment. Currently, Medicaid covers blood tests and follow-up care for children, as do most insurance providers, and the state-run program Dr. Dynasaur.⁷⁵ Approximately 48% of children are insured by Medicaid or Dr. Dynasaur, while 47% of children are insured by private insurance companies that are not mandated to cover these tests.⁷⁶ There is still a risk that insurance companies that currently cover tests and follow-up care could drop coverage. Including mandatory coverage in Vermont's lead law would ensure that all insurance companies cover blood lead testing and follow-up care and avoid any backsliding of those who already cover this care. This is a long-term commitment to 100% insured coverage of basic services and a safeguard measure to protect the health of Vermont children and their families from unnecessary financial burden for generations to come.

Why this policy is necessary:

Hypothetically, a father could bring his child into the doctor's office and be forced, by law, to let his child be tested for blood lead. The doctor could assure him that his insurance would cover the test. It might not be until the medical bill comes that the father realizes his insurance did not cover the test. A blood test typically costs \$40 to \$100, which is a significant expense for a single father trying to make ends meet.⁷⁷ In an even scarier situation, what if the child tests positive for lead contamination but then the insurance will not cover follow-up care? The child bears the health effects while the parent has to scrounge to cover the even higher costs of follow-up care, from further tests to chelation therapy.

⁷⁵ Voices for Vermont Children. 2013. "The State of Our Children: KIDS COUNT in Vermont Health Report." December 2013. <<http://www.voicesforvtrkids.org/wp-content/uploads/The-State-of-Our-Children.pdf>>.

⁷⁶ Vermont Agency of Human Services, Department of Children and Families, Economic Services Division. Via Voices for Vermont's Children. 2014. "Children Enrolled in Medicaid and Dr. Dynasaur." 2007 – 2013. <<http://datacenter.kidscount.org/data/tables/8191-children-enrolled-in-medicaid-and-dr-dynasaur?loc=47&loct=2#detailed/2/any/false/1218,1049,995,932,757/any/15686>>.

⁷⁷ California Department of Health. 2014. "Employer Alert: Low Levels of Lead: Dangerous." <<http://www.cdph.ca.gov/programs/olppp/Documents/EmployerAlert.pdf>>.

i. Precedent in California

There is precedent for this sort of insurance law. California requires all health care service plans and insurance policies to cover blood tests for lead.⁷⁸ Specifically, these statutes are found in the California Health & Safety Code, Section 1367.3 D:

“For health care service plan contracts within the scope of this section that are issued, amended, or renewed on and after January 1, 1993, screening for blood lead levels in children at risk for lead poisoning, as determined by a physician and surgeon affiliated with the plan, when the screening is prescribed by a physician and surgeon affiliated with the plan. This subparagraph shall be applicable to all children and shall not be limited to children 17 and 18 years of age.”⁷⁹

And California Insurance Code, Section 10119.8:

“On and after January 1, 1993, every insurer issuing, amending, or renewing a policy of individual or group disability insurance that covers hospital, medical, or surgical expenses shall offer coverage for screening for blood lead levels for covered children. This section shall not apply to specified accident, specified disease, hospital indemnity, Medicare supplement, or long-term care health insurance policies.”⁸⁰

Vermont legislators should add provisions to Vermont law that are similar to these California laws.

ii. Economic impact of mandatory insurance coverage

Vermont legislators could directly insert these provisions into the law with little difficulty or cost. Implementing mandatory insurance coverage for blood lead tests and follow-up care for children should not cost the state anything. Most insurance companies are already covering these services, so this should not raise insurance provider costs or individual premium payments. Exact numbers for the percentage of insurance companies that already cover lead tests are difficult to find due to the lack of insurance service transparency.

5.3 Conclusion

Vermont needs long-lasting policy to address the persistent issue of lead contamination. Here, we outline two policies that would help Vermont lead policy be more sustainable and forward-thinking. First, a nominal fee of \$0.25 per gallon of paint sold should be implemented to ensure reliable funding for the Healthy Homes Lead Poisoning Prevention Program (HHLPPP). Second, state law should mandate that insurance providers cover childhood blood lead level tests and follow-up care. Policymakers should use these two recommendations as a starting place for improving Vermont lead policy. Notably not addressed here is how to increase compliance with current Vermont law. Funding for expanded education programs would help, particularly in southern Vermont, as would more funding for code enforcement. Policymakers must implement long-term solutions for lead contamination to protect the health of Vermont children for generations to come.

⁷⁸ California Department of Health. 2014. “California Statutes Related to Childhood Lead Poisoning Prevention.” <<http://www.cdph.ca.gov/programs/CLPPB/Pages/AboutCLPPB.aspx#CAstatutes>>.

⁷⁹ California Legislature. 2014. *Health and Safety Code*. <<http://www.leginfo.ca.gov/cgi-bin/displaycode?section=hsc&group=01001-02000&file=1367-1374.195>>.

⁸⁰ Ibid.

6. Conclusion

Although active sources of lead were banned decades ago, lead persists in the environment and continues to impact public health. Results of soil lead tests show that dangerous levels of lead contamination exist in soils across Vermont; there is no major area of the state that does not have homes with soil lead levels above 1200 ppm. Spatial variation of soil lead levels in Burlington appears to be related to the age of housing stock. Additionally, using conservative modelling, our predicted “Roadway Riskscape” highlights areas where homes are vulnerable due to close proximity to roadways, especially along transit corridors. We hope that agencies will create riskscape models similar to ours, but using other risk factors like age of housing stock or historic land use, to proactively test soils *before* patients are found to have high blood lead levels. As new soil test results come in, these data should be added to the soil lead database. In this way the database will become a more powerful tool for observing patterns in the distribution of soil lead in the state. A further idea for modeling risks is to apply the ecological concept of an Element Distribution Model, which analyzes all the environmental parameters of locations where a rare species is known to live to predict other locations where it might be found.⁸¹ When applied to soil lead, this integrative analysis would be able to compare the relative importance of different risk factors and predict specific locations that would be likely to have high soil lead levels.

On the home-scale, soil lead contamination in Vermont is highly variable, but is generally highest close to exterior walls or other structures built prior to 1978. Exposure to lead via residential soils should be easy to eliminate in the majority of Vermont homes with the adoption of a few basic principles. Primarily, these principles are to site gardens and play areas away from walls, and to minimize the amount of soil that can be blown into the house or tracked in on hands or shoes.

Educating Vermonters about the dangers of lead in soil will help reduce the rates of soil-caused lead poisoning. The VDH identified a need for updated outreach materials to communicate the dangers of lead in soil. Our outreach materials, which are guided by principles of psychology and health communication research, are engaging, accessible, and effective at communicating these risks. Our outreach material will be distributed online and as a tri-fold pamphlet. Once our materials are in circulation on the VDH website and at other lead-interested organizations, Vermonters will become more aware of the dangers of lead in soil and of how to reduce their risk of exposure.

Vermont’s lead policy, while better than many neighboring states, has room for improvement. The two policies proposed here (implementing a \$0.25 fee per gallon of paint sold and mandating insurance coverage for blood lead tests and follow-up care) will ensure that more Vermont children are protected from lead contamination. More work on policy must be done, particularly on improving compliance with current Vermont law. Policymakers should look to other states for precedents on how to protect future generations of Vermont children from the persistent problem of lead contamination.

Overall, we believe that the problem of lead poisoning as a result of soil lead contamination is a manageable problem if Vermont takes a proactive stance. With such an old housing stock, it is necessary that the state and other organizations take soil lead as seriously as interior lead paint as a pathway to lead poisoning. With education, tightened policy, and

⁸¹ Guisan, A., and Zimmermann, N. E. 2000. Predictive habitat distribution models in ecology. *Ecological Modelling* 135(2–3), pg 147–186.

proactive soil testing, many Vermont families could be saved from the stress and health effects of lead poisoning. This report embodies the first steps along this path. We hope that Vermont leaders will build upon our findings and implement our recommendations as the knowledge of soil lead in Vermont continues to expand.

Acknowledgements

A huge “thank you” to everyone who helped us along this journey of trying to fix the problem of lead contamination in Vermont soils. We hope we’ve put a dent in the the problem and built a foundation of work that will help prevent lead poisoning across Vermont for years to come. To Andrea Haugen at the VDH: a million thanks for your patience with all of our questions, for sharing your wealth of knowledge about lead contamination in Vermont, and for giving us many rounds of feedback on our initially scattered content. We hope our work will help the HHLPPP in your essential and sometimes overlooked work to protect the health of Vermonters. To Senator Ginny Lyons: Thank you for encouraging our exploration of Vermont policy while giving crucial realistic feedback to our policy recommendations. We hope you can steer some of our proposal into law!

We would also like to thank Ron Rupp at the Vermont Housing Conservation Board, and the folks at the Burlington Lead Program for sharing soil lead data with us; Professor Jim Larrabee, Professor Molly Costanza-Robinson, and the students of CHEM0311 for reanalyzing our samples with GFAAS; Professor Dave Allen with the Biology Department for assisting us in creating our drip zone model; the digital media tutors at the Wilson Media Lab for helping us learn to use Adobe Illustrator; Bill Hegman and Professor Jeff Howarth with the Geography Department for offering us their enormous expertise on geographic analyses and map creation; and finally all of the people who let us test their yards for lead. Without you all, we could not have made it this far. Thank you.

Last, an especially heartfelt thanks to our brilliant professors Mez Baker-Medard and Diane Munroe. Your tireless work and feedback has helped to shape our project into something meaningful, both for the state of Vermont and for us.

Appendix A: List of Supporting Materials

The list below contains the data files used to create the materials in this report, and editable versions of those materials. These materials are available through Middlebury College by contacting Diane Munroe, Coordinator for Community-Based Environmental Studies, at dmunroe@middlebury.edu.

A.1 Maps

- **ArcMap Workflow- Adding data to the Soil Lead Spatial Database** — Workflow used to create map of existing soil lead testing in Vermont. (.DOCX)
- **Soil Lead Database** — Data used to create map of existing soil lead testing in Vermont. (.XLSX)
- **VT_Soil_Lead_Map** — Copy of Figure 4 from the report with an additional explanatory caption. Depicts existing soil lead testing data in Vermont. (.PDF & .JPEG)
- **VT_Soil_Lead_Map_for report** — Copy of Figure 4 from the report. No caption. (.PDF & .JPEG)
- **Burlington_Soil_Lead_Map** — Copy of Figure 5 from the report with an additional explanatory caption. Depicts existing soil lead testing data in Burlington, Vermont. (.PDF & .JPEG)
- **Burlington_Soil_Lead_Map_for report** — Copy of Figure 5 from the report. No caption. (.PDF & .JPEG)
- **Soil Lead Spatial Database** — Folder containing the suite of ArcGIS files associated with the map of existing soil lead testing in Vermont. Contains the following:
 - **Soil_Lead_Spatial_Database** (.MXD)
 - **VT_Soil_Lead_Map** (.MXD)
 - **VT_Soil_Lead_Map_for report** (.MXD)
 - **Burlington_Soil_Lead_Map** (.MXD)
 - **Burlington_Soil_Lead_Map_for report** (.MXD)
 - **DEMO_COUSUB2010_POLY** (.DBF, .PRJ, .SBN, .SBX, .SHP, .SHX, .HTML, .TXT, & .XML)
 - **Emergency_RDS_line** (.DBF, .PRJ, .SBN, .SBX, .SHP, & .SHX)
 - **EmergencyE911_RDS** (.HTML & .TXT)
 - **Highways** (.CPG, .DBF, .PRJ, .SBN, .SBX, .SHP, & .SHX)
 - **Soil_Lead_Levels** (.CPG, .DBF, .PRJ, .SBN, .SBX, .SHP, & .SHX)
 - **Water_Shape** (.CPG, .DBF, .PRJ, .SBN, .SBX, .SHP, & .SHX)
- **Predictive Geographic Workflow** — ArcGIS workflow for predictive riskscape analysis. (.DOCX)
- **Predictive Soil Riskscape Excel Data** — Data used to create map of proximity houses to major roads in Vermont. (.XLSX)
- **Lead Riskscape** — Copy of Figure 6 from report. (.PDF)
- **Burlington Road Lead Risk** — Copy of Figure 7 from the report. (.PDF)
- **Raw Data** — Folder containing original E911 point data for homes and tiger files for roadways.
 - **E911 Housing Data** (.DBF, .PRJ, .SBN, .SBX, & .SHP)
 - **Roads Traffic** (.DBF, .PRJ, .SBN, .SBX, & .SHP)

- **Riskscape Data** — Folder containing analyzed and calculated dataset of soil lead risk around Vermont roadways.
 - **Riskied Homes** (.DBF, .PRJ, .SBN, .SBX, & .SHP)
 - **Trans_Classed** (Calculated Roads Dataset) (.DBF, .PRJ, .SBN, .SBX, & .SHP)

A.2 Drip Zones

- **Drip_zone_fielddata** — Niton XRF data used to build the drip zone model. Includes data on Mo, Sr, Zr, Rb, Se, As, Hg, Zn, Cu, Ni, Co, Fe, Mn, and Cr levels in addition to Pb. (.CSV)
- **Drip_zone_model_graph** — Copy of Figure 8 from the report. Depicts the drip zone soil lead level model. (.JPEG)
- **Drip_zone_methods_comp** — Data used to compare methods of determining soil lead level. Includes data for GFAAS, XRF field readings, and XRF readings on dry, homogenized samples for 2 transects (N=22). (.XLSX)
- **Burlington_soil** — Preliminary data for 4 houses in Burlington. This data was not used in the drip zone analysis. Includes data on Mo, Sr, Zr, Rb, Se, As, Hg, Zn, Cu, Ni, Co, Fe, Mn, and Cr levels in addition to Pb. (.XLSX)
- **Drip_zone_R** — R code used to build drip zone model and raw results of that model. (.HTML)

A.3 Outreach

- **brochure final** — Educational outreach brochure for lead in soil pictured in Section 4: Public Outreach. (.AI & .PDF)
- **Lead web final4** — Educational outreach material for website pictured in Section 4: Public Outreach. (.AI & .PDF)